Juniper® Validated Design

JVD Test Report Brief: Metro Ethernet Business Services

Introduction

This Juniper Validated Design testing focused on evaluating the design of Metro Ethernet Business Services, specifically for E-Line/E-LAN/E-Access metro services based on a next-generation Seamless Segment Routing transport infrastructure, incorporating ACX7024 (DUT), ACX7100-48L (DUT), MX204, ACX5448, and ACX710 as access nodes. The ACX7100-32C (DUT) and ACX7509 (DUT) platforms support lean edge solutions, offering connectivity options into cloud compute complexes. The MX304 (DUT) supports multiservices edge (MSE) functionality to facilitate complex connectivity and Internet access. PTX10001-36MR supports core and peering roles.

The solution delivers the integration of traditional metro ring architectures with multi-instance ISIS, Flex-Algo Prefix Metric (FAPM) into NG SR-MPLS metro fabrics leveraging inter-domain transport class and Inter-AS BGP-CT with end-to-end multi-domain service mapping. Connectivity options for port (EPL) and VLAN (EVPL) IEEE 802.1q/QinQ based EVC's supporting end-to-end active-active highly available services including EVPN-VPWS/FXC/EVPN-ELAN and co-existing with traditional VPN services including multi-site VPLS, hot-standby L2Circuit, L2VPN and L3VPN with DIA (Dedicated Internet Access). Legacy static PWs are migrated to an Anycast Floating PW (AFPW) solution, leveraging Anycast-SID for L2 QinQ connectivity. Layer 2 services include E-OAM performance monitoring.

Test Topology

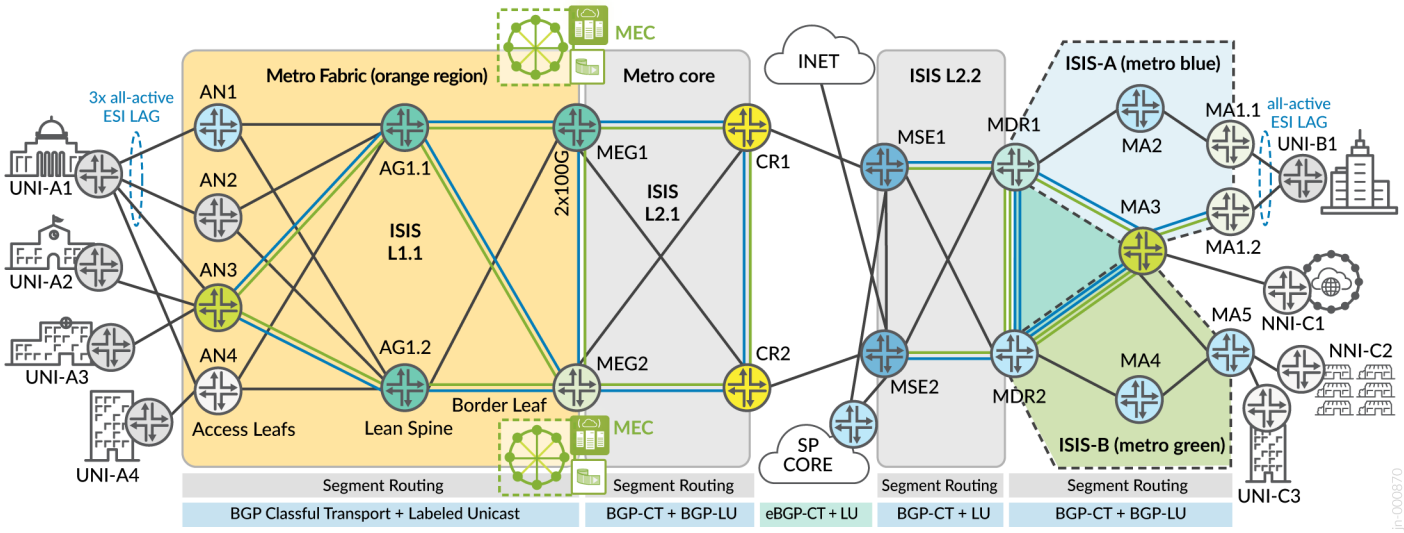

Figure 1: Metro EBS Solution Topology

Platforms Tested

Table 1: Platforms Used

Role	Platform	OS
Access Node AN1	MX204	Junos OS Release 23.2R2
Access Node AN2	ACX5448	Junos OS Release 23.2R2
Access Node (DUT) AN3	ACX7100-48L	Junos OS Evolved Release 23.2R2
Access Node AN4	ACX710	Junos OS Release 23.2R2
Aggregation Node AG1.1	ACX7100-32C	Junos OS Evolved Release 23.2R2
Aggregation Node AG1.2	ACX7100-32C	Junos OS Evolved Release 23.2R2
Metro Edge Gateway (DUT) MEG1	ACX7100-32C	Junos OS Evolved Release 23.2R2
Metro Edge Gateway (DUT) MEG2	ACX7509	Junos OS Evolved Release 23.2R2
Core Router CR1	PTX10001-36MR	Junos OS Evolved Release 23.2R2
Core Router CR2	PTX10001-36MR	Junos OS Evolved Release 23.2R2
Multiservice Edge (DUT) MSE1	MX304	Junos OS Release 23.2R2
Multiservice Edge (DUT) MSE2	MX304	Junos OS Release 23.2R2
Metro Distribution Router MDR1	ACX7509	Junos OS Evolved Release 23.2R2
Metro Distribution Router MDR2	MX10003	Junos OS Release 23.2R2
Metro Access MA2	MX204	Junos OS Release 23.2R2
Metro Access MA3	ACX7100-48L	Junos OS Evolved Release 23.2R2
Metro Access MA4	MX204	Junos OS Release 23.2R2
Metro Access MA5	MX204	Junos OS Release 23.2R2
Metro Access (DUT) MA1.1	ACX7024	Junos OS Evolved Release 23.2R2
Metro Access (DUT) MA1.2	ACX7024	Junos OS Evolved Release 23.2R2
UNI-A1	ACX5448	Junos OS Release 23.2R2
UNI-B1	ACX5448	Junos OS Release 23.2R2
Switches used for Multi-homing LAG	QFX5110-48s-4c	Junos OS Release 23.2R2
	QFX5110-48s4c	Junos OS Release 23.2R2

Version Qualification History

This JVD has been qualified in Junos OS Release 23.2R2 and Junos OS Evolved Release 23.2R2.

Scale and Service Details

Table 2: Scale Numbers for the Devices Under Test (DUTs)

Devices Under Test Scale							
Feature	**AN3 ACX7100-48L**	**MEG1 ACX7100-32C**	**MEG2 ACX7509**	**MSE1 MX304**	**MSE2 MX304**	**MA1.1 ACX7024**	**MA1.2 ACX7024**
IFD	66	50	48	115	108	35	35
IFL	8581	4249	3945	16333	13776	789	1512
VLANs per-system	6064	3064	3061	7745	5686	600	830
ISIS Adjacency IPv4	4	7	9	4	3	2	2
IBGP v4 Sessions	2	7	7	8	3	4	4
EBGP sessions	200	2	2	2201	2203	-	-
RIB routes	~279k	~155k	~154k	~349k	~1.2M	~31k	~33k
FIB routes	~65k	~12k	~12k	~113k	~966k	~4k	~4k
EVPN-VPWS SH	200	-	-	-	-	-	-
EVPN-FXC SH VLAN-unaware	500	-	-	500	-	-	-
EVPN-FXC SH VLAN-aware	-	-	-	-	-	-	-
EVPN-FXC MH VLAN-aware	0	50	50	-	-	50	50
EVPN-VPWS A/A MH	1400	1000	1000	-	-	400	400
EVPN-ELAN MH VLAN-bundle	200	200	200	-	-	-	-
EVPN-ELAN MH VLAN-based	100	100	100	-	-	100	100
EVPN-ETREE	-	-	-	1000	1000	-	-
EVPN TYPE-5	50	50	50	50	50	-	-
EVPN Anycast IRB	25	25	25	25	25	-	-
EVPN-VPWS EPL	1	-	-	-	-	1	-
EVPN-ELAN EPL	1	-	-	-	-	-	1
EVPN Floating PW	-	-	-	100	100	-	100
L2VPN EPL	1	-	-	-	-	-	-
L2Circuit Hot Standby	1000	1000	1000	-	-	-	-
L2 VPN Sessions	200	-	-	-	-	-	-
L3VPN BGPv4 Instances	100	-	-	1100	1100	-	-
L3VPN BGPv6 Instances	100	-	-	1100	1100	-	-
L3VPN OSPF Instances	100	-	-	1100	1100	-	-
VPLS Instances	300	200	100	-	-	-	200
MAC Scale - VPLS	900	600	300	-	-	-	500
CFM UP MEP	1000	400	200	-	-	-	300

TOTAL VPN SERVICES	4278	2525	2525	4975	4475	551	851

Convergence Data

The JVD team validated the reference architecture for Metro Ethernet Business Services, encompassing over twenty service-delivery use cases across multi-domain and inter-AS seamless segment routing infrastructure. The network includes controller-less lite-slicing solutions with flex-algo, transport classes, and service mapping. The validation includes MX304, ACX7024, ACX7100-48L, ACX7100-32C and ACX7509 as primary DUTs with helper nodes including PTX10001-36MR, MX204, MX10003, ACX5448, ACX710, QFX5110 platforms. Over 300 test cases are executed successfully in the course of validation on Junos OS and Junos OS Evolved version 23.2R2.

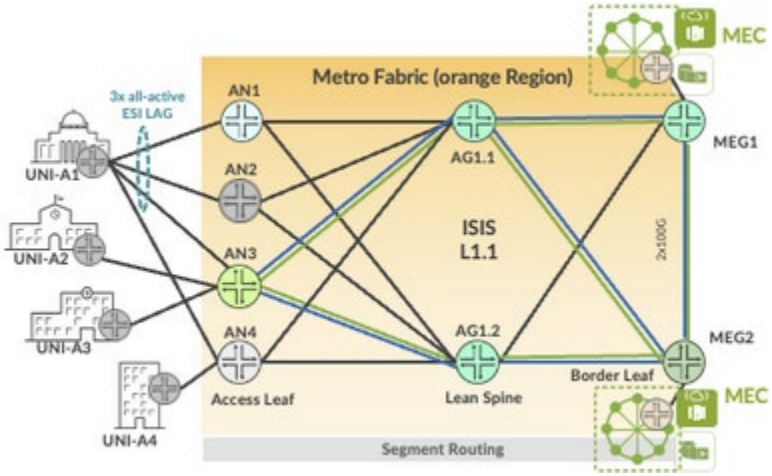

Figure 2: Metro EBS Solution Topology

The next table summarizes convergence times for metro fabric services for the given failure event. The fabric design enables flow optimization for AN-to-AN VPN service. Intra-AS metro fabric services include AN-to-AN (via spine), AN-to-MEG single-homing, and AN-MEG1/MEG2 multi-homing. The Metro Edge Gateway (MEG) supports the connectivity into edge computing services.

Table 3: Scale Numbers for the Devices Under Test (DUTs)

METRO FABRIC INTRA-AS (milliseconds)								
	EVPN-VPWS		EVPN-ELAN		L2CIRCUIT		L3VPN	
EVENT	COLOR AWARE	COLOR AGNOSTIC	COLOR AWARE	COLOR AGNOSTIC	COLOR AWARE	COLOR AGNOSTIC	COLOR AWARE	COLOR AGNOSTIC
AN3-AG1.1 link disable	0	2.3	87	3	0	4.8	0	2.8
AN3-AG1.1 link enable	0	0	0	0	1	1.4	0	0
AN3-AG1.2 link disable	0.3	1	0.2	0.2	1.2	0.7	0	0.3
AN3-AG1.2 link enable	0	0	46.6	0	0.8	1.5	0	0
AG1.2-MEG2 link disable	0.7	1	0.7	0.7	1.3	1.3	0	0.6
AG1.2-MEG2 link enable	0	0	0	0	0	0	0	0
AG1.1-MEG1 link disable	49.6	0.3	20.1	0.3	42	0	0	0
AG1.1-MEG1 link enable	0	0	0.2	0.1	0	0	0	0
L2CKT Standby Failover	-	-	-	-	2939.8	2443	-	-
L2CKT Standby Revert	-	-	-	-	39	43	-	-

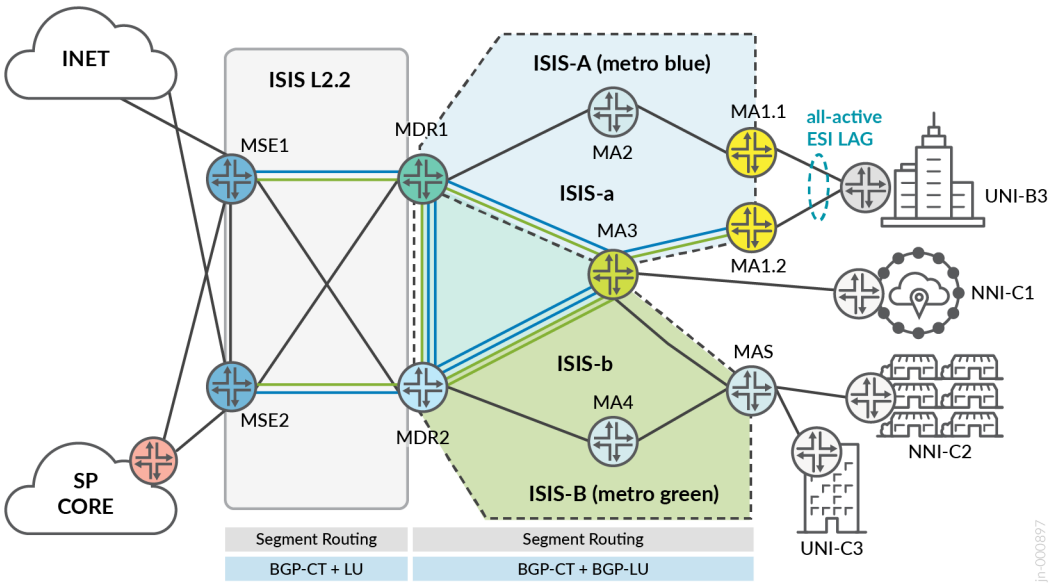

Figure 3: Metro Multi-Ring Topology

The next table summarizes convergence times for metro multi-ring services for the given failure event. The multi-ring design enables flow optimization for MA-to-MA VPN services by leveraging MDR1/MDR2 as the point of prefix leaking between ring domains (ISIS instances). Intra-AS metro multi-ring services include MA-to-MA, MA-to-MSE single-homing, and MA-MSE1/MSE2 multi-homing. The Multiservices Edge (MSE) routers support Internet-VRF and SP core connectivity, which allows services to be stitched into additional network domains.

Table 4: Convergence times for Metro Multi-Ring Services

METRO MULTI-RING INTRA-AS (milliseconds)								
	BGP-VPLS		EVPN-TREE		FLOATING PW		L3VPN	
EVENT	COLOR AWARE	COLOR AGNOSTIC	COLOR AWARE	COLOR AGNOSTIC	COLOR AWARE	COLOR AGNOSTIC	COLOR AWARE	COLOR AGNOSTIC
MDR1-MA2 link disable	0	0	0	0	0	0	0	0
MDR1-MA2 link enable	17.5	0	0	0	0	0	0	0
MDR1-MA3 link disable	0	0	0	0	1.3	0.4	1	1
MDR1-MA3 link enable	0	0	0	0	1.4	0.7	0	0
MDR2-MA3 link disable	0	0	0	0	37.2	29.4	0.4	0
MDR2-MA3 link enable	0	0	0	0	1.4	0	6.3	0
MDR2-MA4 link disable	22.4	35.9	48.3	48.6	0	0	50	50
MDR2-MA4 link enable	0	0	0	0	0	0	0	0
MA1.2-MA3 link disable	115.3	178.3	0	0	67.4	18.4	0	0
MA1.2-MA3 link enable	12.6	12.8	0	0	6.1	0	0	0
SP Core to MSE2 link disable[1]	-	-	28.1	131.7	8.8	6.6	-	-
SP Core to MSE2 link enable[1]	-	-	32.4	31.7	84	412	-	-

[1] SP Core represents a Q-in-Q segment handoff.

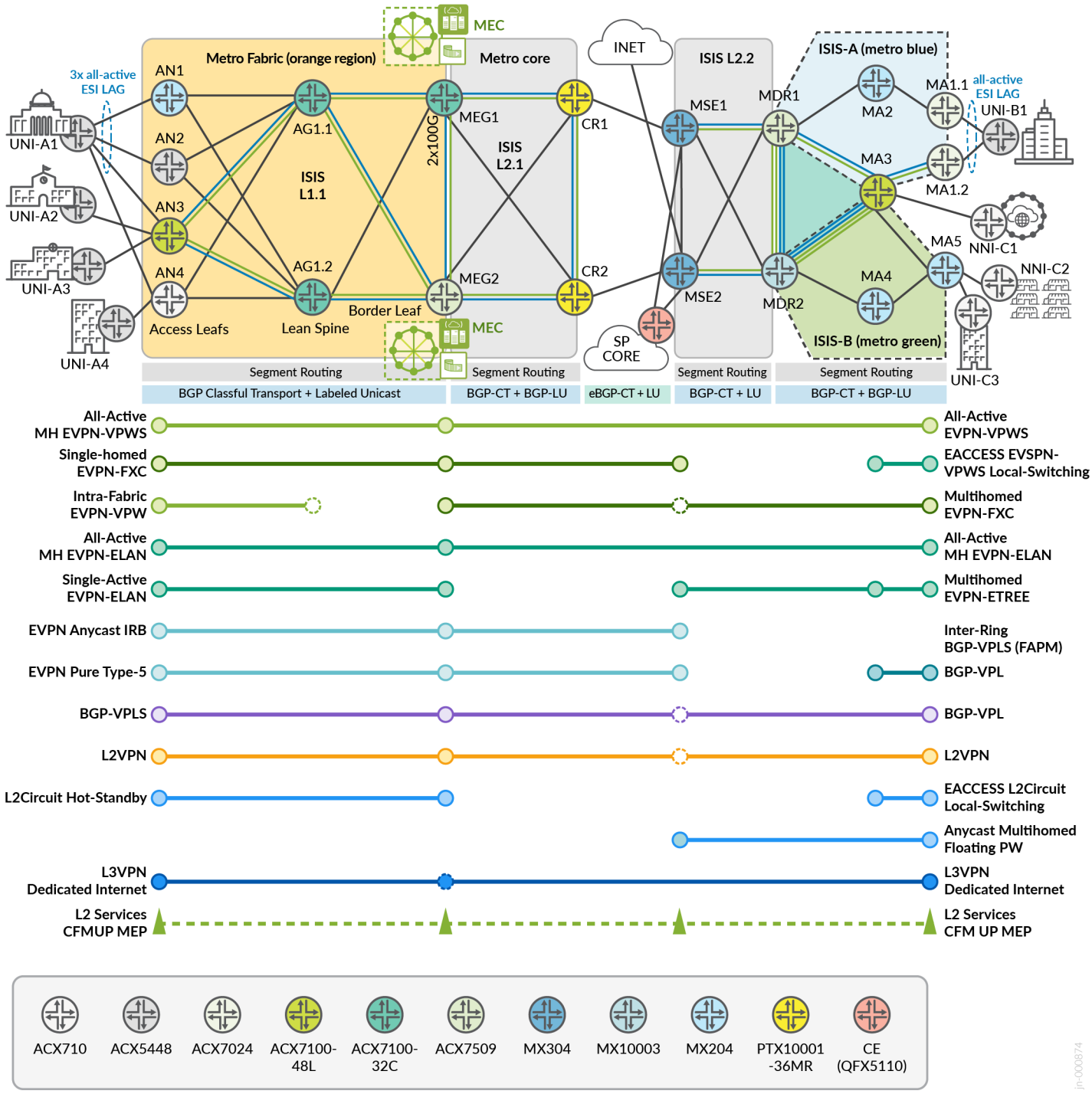

Figure 4: Metro Fabric to Multi-Ring Inter-AS Topology

The next convergence table includes the end-to-end inter-AS services.

Table 5: Convergence Times for End-to-End Inter-AS Services

METRO MULTI-RING INTRA-AS (milliseconds)										
	EVPN-VPWS		EVPN-ELAN		L2VPN		VPLS		L3VPN	
EVENT	COLOR AWARE	COLOR AGNOSTIC	COLOR AWARE	COLOR AGNOSTIC	COLOR AWARE	COLOR AGNOSTIC	COLOR AWARE	COLOR AGNOSTIC	COLOR AWARE	COLOR AGNOSTIC
AN3-AG1.1 link disable	0	0	-	0	0	0	87	0	0	0
AN3-AG1.1 link enable	0	0	-	0	1	1.4	0	0	0	0
AN3-AG1.2 link disable	0	0.8	0.18	0.8	0	0.8	0.4	0.8	1	1
AN3-AG1.2 link enable	0	0	0	0	0	0	0	0	0	0
AG1.2-MEG2 link disable	0	1.4	0.6	1.4	0.7	1.4	0.7	1.4	1.4	1.4
AG1.2-MEG2 link enable	0.7	0	0	0	0	0	0	0	0	0
AG1.1-MEG1 link disable	0	0.7	0.7	0.2	0	0	0.1	0	0	0
AG1.1-MEG1 link enable	0	0.5	0.4	0.2	0	0	0.4	0.2	0.4	0
MDR1-MA2 link disable	1.9	3.4	0	1.7	0	0	0	0	0	0
MDR1-MA2 link enable	0.4	10.6	1.2	3.79	0	0	0	0	0	0
MDR1-MA3 link disable	0.2	0.1	0.4	0.19	0	0.4	0.3	2.1	0	0
MDR1-MA3 link enable	0.4	0.4	3.9	0.2	0	0.1	0.8	1.5	0.1	0
MDR2-MA3 link disable	11.3	19	0.6	12.5	1.24	0.3	14.7	37.7	0.5	0
MDR2-MA3 link enable	0	26.9	0.2	0.1	38.6	0.1	0.1	1.6	0.1	0
MDR2-MA4 link disable	0	0	0	0	18.4	25.4	22.4	0	0	0
MDR2-MA4 link enable	0	0	0	0	0	0	0	0	0	0
MA1.2-MA3 link disable	54.9	9.6	-	-	0	0	18.4	61.9	0	0
MA1.2-MA3 link enable	11.6	0.4	-	-	0	0	0.1	13.9	0	0

AN3 ESI LAG disable	-	2.2	1099.4[1]	1075.6[1]	-	-	-	-	-	-
AN3 ESI LAG enable	-	1.8	38.1	38.1	-	-	-	-	-	-
MEG-MEC link disable	579.1[1]	571.9[1]	909.9[1]	915.1[1]	-	-	-	-	-	0
MEG-MEC link enable	144.8[1]	232.8[1]	1420[1]	71.5[1]	-	-	-	-	-	81.5

[1] Current result shows global repair. For fast fail over, the dynamic-list-next-hop (DLNH) feature is required. It is scheduled for Junos OS-Evolved Release 24.3.

Traffic Profiles

Table 6: Custom IMIX Definition

Custom IMIX Table	
Size	**Weight**
64	3
128	16
256	6

Table 7: Traffic Load Distribution

Traffic Load Distribution		
Feature	**Aggregate FPS**	**Packet Sizes Tested**
L2Circuit-HSB	322983	Custom IMIX
L2Circuit-HSB	2400	512
Floating-PW	322982	Custom IMIX
Floating-PW	1600	512
EVPN-VPWS-SH	11000	Custom IMIX
EVPN-VPWS-SH	1200	512
EVPN-FXC-SH-unaware	432984	Custom IMIX
EVPN-FXC-SH-unaware	2400	512
EVPN-FXC-MH-aware	21395.5	Custom IMIX
EVPN-FXC-MH-aware	4800	512
EVPN-ETREE	64596	Custom IMIX
EVPN-ETREE	12000	512
VPLS	446023	Custom IMIX
VPLS	14400	512
L2VPN	40000	Custom IMIX
L2VPN	1200	512
EVPN-ELAN-MH-VLAN-bundle	322983.5	Custom IMIX
L3VPN-OSPF	88000	Custom IMIX
L3VPN-BGPv4	88000	Custom IMIX
L3VPN-BGP-v6	8000	Custom IMIX
EVPN-ELAN-MH-VLAN-based	1078952	Custom IMIX
EVPN-ELAN-MH-VLAN-based	3600	512
EVPN-TYPE-5	140000	Custom IMIX
L3VPN-BGPv4-INTERNET	40000	Custom IMIX
EVPN-VPWS-MH	60000	Custom IMIX
EVPN-VPWS-MH	5400	512
EVPN-VPWS-LSW	20000	Custom IMIX
EVPN-VPWS-LSW	1200	512
L2Circuit-LSW	16149	Custom IMIX
L2Circuit-LSW	3000	512
EVPN-VPWS-EPL	60000	Custom IMIX
L2VPN-EPL	60000	Custom IMIX

EVPN-ELAN-EPL	60000	Custom IMIX
L3VPN-BGP-INTERNET	20000	Custom IMIX
L3VPN-BGP-v6_INTERNET	60000	Custom IMIX
EVPN - Anycast IRB	100000	Custom IMIX
EVPN-TYPE-5-INTERNET	20000	Custom IMIX

High Level Features Tested

Common Features:

- Seamless SR-MPLS with TI-LFA
- Flexible Algorithm Application Specific Link Attribute (ASLA)
- Co-Existence of Seamless SR-MPLS BGP-LU and BGP-CT Inter-AS solutions
- End-to-End color-aware Traffic Steering (Network “Lite-Slicing”)
- Intra-domain Transport Class tunneling with Service Mapping
- Inter-domain color awareness with BGP Classful Transport
- All services include color-aware and color-agnostic path selection
- Intent-based routing with Color Mapping based on Delay and TE metrics
- Color agnostic services take IGP metric paths (inet.3)
- Strict Resolution Scheme (no fallback) and Cascade Fallback

Metro Fabric Features:

- Lean Edge services aggregation
- Metro Edge Gateway with Multi-access Edge Compute Interconnectivity
- Optimized forwarding paths over 2-stage MPLS fabric
- EVPN-FXC (aware + unaware), EVPN-VPWS, EVPN-ELAN
- L2Circuit, L2VPN, BGP-VPLS
- Dedicated Internet Access (DIA): L3VPN, EVPN Type-5
- All-Active ESI LAG load-shared x3 PEs

- Active-Active and Hot-Standby Services
- Policer scale

Metro Rings Features:

- Multi-Instance ISIS (blue and green rings)
- Flex-Algo Prefix Metrics (FAPM) Leaking across ISIS Multi-Instances to optimize inter-ring forwarding paths
- Intra-domain Transport Class Service Mapping
- Floating PW with Anycast-SID (migrating from legacy L2CKT)
- EVPN-ETREE (MX-only), EVPN-FXC, EVPN-VPWS, EVPN-ELAN, L2Circuit, L2VPN, BGP-VPLS
- Local Switching (LSW) EVPN-VPWS and L2Circuit
- L3VPN

Known Limitations

- The solutions and services proposed by the JVD can be considered complete and supported with the following distinctions. Note that any target Junos OS/Junos OS Evolved feature delivery references are not guaranteed and are subject to delay or cancellation without notice. Contact your Juniper Networks representative for status.
- Juniper recommends two additional optimization options for improving EVPN performance and reducing convergence time. For EVPN active-active multi-homing, the ESI route by default points to two next hops. A link failure event between PE and CE causes a new next-hop entry to be created, triggering mass MAC route withdrawals and additions. Juniper recommends Dynamic List Next Hop (DLNH) to enable silent removal of the affected next-hop entry without causing mass MAC withdrawals. EVPN Egress Link Protectionhttps://www.juniper.net/documentation/us/en/software/junos/evpn-vxlan/topics/concept/convergence-mh-evpn-mpls.html creates backup next hops on multi-homed PEs to support fast reroute (FRR). These features are currently supported on MX platforms. The ACX7000 family does not support these features in Junos OS Evolved Release 23.2R but support is planned for Junos OS Evolved Release 24.3R1.
- To avoid certain BGP-LU and BGP-CT inter-domain global repair events, Juniper recommends BGP-PIC machinery. In the presented solution, the functionality requires the preserve-nexthop-hierarchy knob, which is supported by MX platforms and included in the JVD. The ACX7000 family targets Junos OS Evolved Release 24.2R1 for these features. BGP-PIC for Seamless SR (BGP-LU and BGP-CT) is not included in the JVD for unsupported devices.
- BGP Classful Transport is included and validated on all featured DUTs running Junos OS Evolved Release 23.2R2. This feature enables seamless inter-domain color transport but is not required for the solution. Contact your Juniper Networks representative with questions or concerns.
- As of Junos OS Evolved Release 23.2R2, the ACX7000 family does not support simultaneous ECMP + FRR mechanisms. In general, TI-LFA fast reroute will provide optimal restoration and these are the results reported in the JVD. Support for the

coexistence of ECMP+FRR is currently planned for Junos OS Evolved Release 24.1R1 and presents opportunities to further improve network resiliency and reduce convergence.

- In EVPN-MPLS scenarios, where the underlay resolves using a recursive route (like SR-TE or BGP-LU scenarios), underlay changes can result in service route next hop changes. If there is a quick underlay flap and the original service route next hop to a remote-PE/BD is reused, the remote-PE may be missing from the flood-next hop list of the corresponding BD. This limitation is resolved with the introduction of the `preserve-nexthop-hierarchy` with `multipath-resolve` configuration options.

Event Testing

The following events have been tested:

- Restart and kill of critical Junos OS or Junos OS Evolved processes and assessing the impact.
- Device reboot to evaluate the impact on the network.
- Interface flap events to evaluate the impact on the traffic.
- Deletion or configuration of various configuration stanzas to evaluate the impact of node and network stability.
- Clearing protocol sessions to simulate protocol session flaps and assess the impact on services and traffic.

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