Lab Testing Summary Report

January 2015

Report SR140730F

Product Category:

Supervisor Engine

Vendor Tested:

CISCO

Product Tested:

Catalyst 4500E Supervisor Engine 8-E

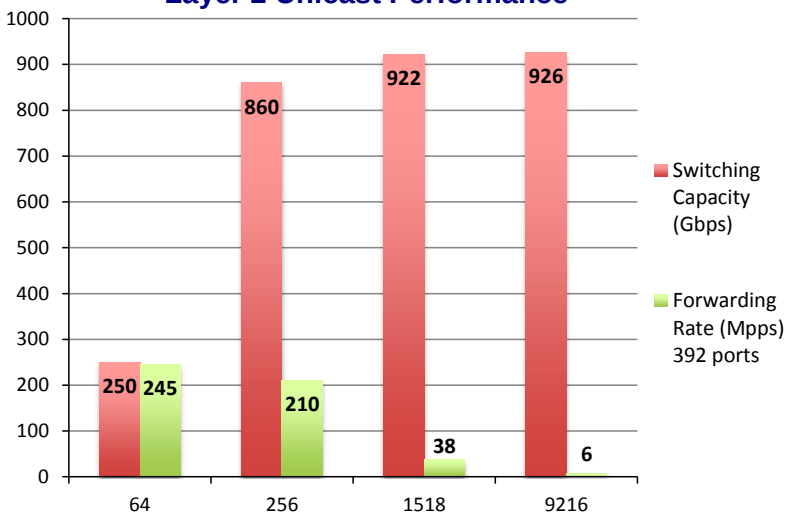
Miercom PERFORMANCE VERIFIED

Key findings and conclusions:

- **Tests achieved over 926 Gbps of L2 and L3 switching capacity and over 240 million packets/sec forwarding rates, with traffic applied on 384 GigE ports on eight 48-port line cards, and on the 8 SFP+ ports on the Supervisor 8-E – a 78 Gbps increase over Sup7-E**
- **Multicast tests achieved over 780 Gbps of throughput; latency is consistently low, under 15 microseconds for most packet sizes**
- **9000W power supply is energy efficient and provides 3 power inputs for flexibility of operation and redundancy and can support up to 384 PoE / 117 UPoE ports**
- **Supervisor Engine 8-E offers features such as Flexible NetFlow, Onboard Packet Analyzer (Wireshark) and Service Discovery Gateway (ZeroConf service discovery across VLANS) that were verified successfully for functionality and scale**
- **Supervisor 8-E supports Converged Access in the IOS XE 3.7 release. The Unified Access Data Plane (UADP) ASIC on Supervisor 8-E provides wireless controller functionality, future-proofing networks against evolving wireless 802.11 standards. The Converged Access architecture extends features such as Quality of Service (QoS), Flexible Netflow (FNF) and Wireshark that were traditionally available for wired traffic to wireless traffic**
- **Supervisor Engine 8-E is capable of supporting SDN and OpenFlow through its flexible architecture so that customers continue to get investment protection as their networks evolve**

Cisco engaged Miercom to verify the performance and advanced features of the Catalyst 4500E Series Supervisor Engine 8-E. Miercom engineers utilized cutting-edge test equipment and techniques to certify the unprecedented performance of the new supervisor engine, verify advanced features such as Service Discovery Gateway, and also to test the full backward compatibility of features

Figure 1: Catalyst 4500E Supervisor Engine 8-E Layer 2 Unicast Performance



Source: Miercom, January 2015

Switching capacity – total user bi-directional data switched, in Gbps – and packets-per-second forwarding rates for Layer 2 unicast traffic are shown by packet size.

such as Flexible Netflow, Wireshark, Stateful Switchover, In Service Software Upgrade and Virtual Switching System.

Supervisor Engine 8-E supports configurations with up to 384 Gigabit Ethernet (1GE) access ports, up to 384 non-blocking 1GE fiber ports or up to 104 10-Gigabit Ethernet (10GE) fiber ports. The recently launched portfolio of 47xx series of 12/24/48 port fiber line cards can provide line rate performance and also supports SGT/SGACL (TrustSec) and MACSec capability. Latest Catalyst 4500E Supervisor Engine 8-E provides eight SFP+ uplinks, boosts performance significantly, and adds cutting edge features to Sup7-E's already impressive repertoire of features. The eight SFP+ uplinks support line-rate 10G MACSec encryption and Cisco TrustSec network device authentication. The Catalyst 4500E uses a single IOS XE image.

High-availability features such as Stateful Switchover (SSO), Non-Stop Forwarding (NSF), In-Service Software Upgrade (ISSU) and Virtual Switching System (VSS) provide reliability and foolproof failover for link failures. Additionally, 1 + 1 redundancy in power supplies also provides resilience during power supply failures. Testing confirmed near instantaneous failover of links, switches and power supplies.

The Supervisor Engine 8-E was evaluated for throughput and latency in accordance with standardized Internet Requests for Comments (RFCs), notably RFC 2544 for unicast benchmarking and RFC 3918 for multicast benchmarking. These specifications address how to measure throughput and latency for traffic types including:

- Layer 2 unicast
- Layer 3 IPv4/IPv6 unicast
- Layer 2/3 multicast

Unicast tests were done with 392 ports arranged in pairs sending bi-directional traffic sent and received by Spirent test systems. Multicast traffic was sent with one transmit (ingress) port and 391 receive (egress) ports. The switching capacities and forwarding rates in this report are the maximum that could be achieved with no packet loss.

High Availability, UPoE (Universal Power over Ethernet) capabilities, Flexible NetFlow, integrated Wireshark decode and analysis software, Service Discovery Gateway and 9000W power supply capabilities were also tested.

This testing was performed with two different test bed configurations. The first test bed comprised of a fully populated single Catalyst 4500E switch for throughput and latency measurements. This test bed included a Spirent TestCenter for traffic testing.

The second test bed comprised of two Catalyst 4500E switches with IXIA test equipment. In this test bed, initially only one Catalyst 4500E switch was used for testing ISSU (In-Service Software Upgrade), Flexible NetFlow, onboard Wireshark, Service Discovery Gateway and the 9000W power supply. This second test bed was then configured in a Virtual Switching System (VSS) topology using two Catalyst 4500E switches to exercise high-availability across the two Catalyst 4500E switches.

Layer 2 Unicast Performance

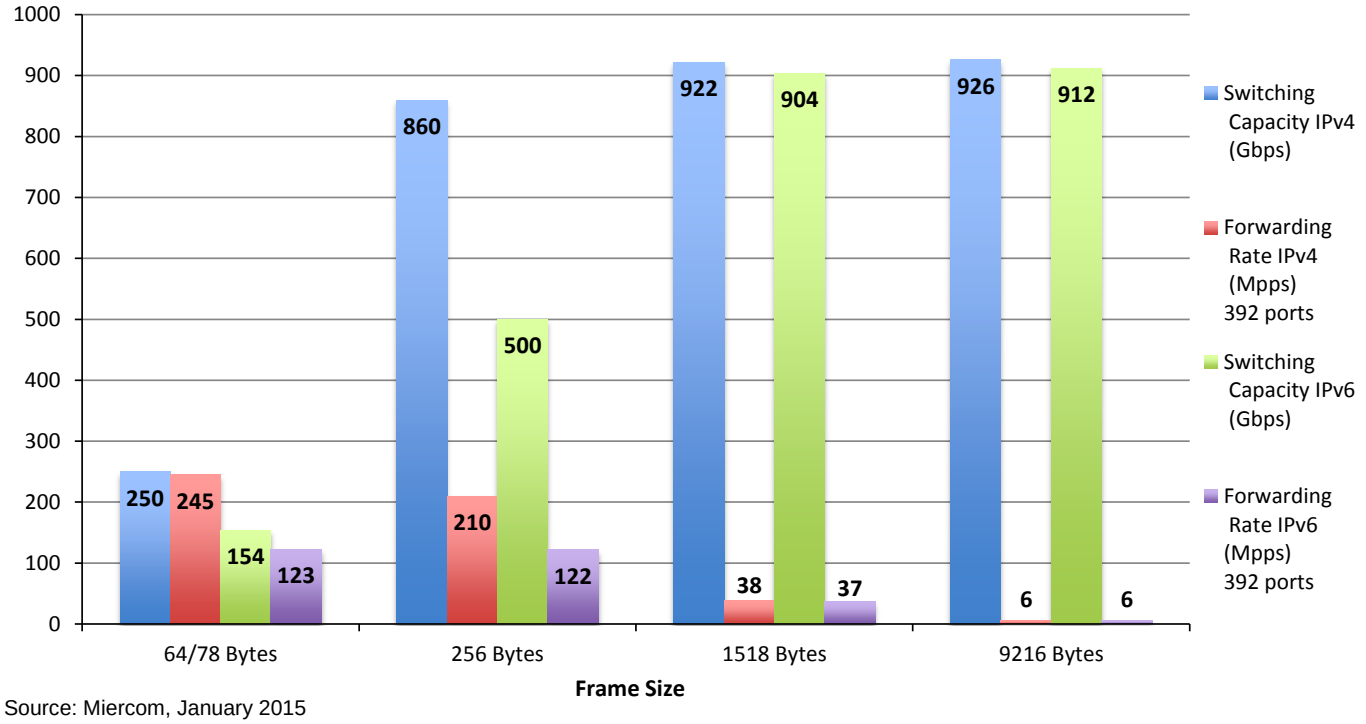
Load testing was conducted for a range of packet sizes to determine the maximum switched throughput and the maximum packet rate in packets per second (pps) for the following frame sizes: 64 bytes, 256 bytes, 1518 bytes and 9216 bytes (jumbo frames).

The Supervisor Engine 8-E achieved the highest switching capacity, 926 Gbps bidirectional, with the 9216-byte frames. The highest packet forwarding rate of 245 Mpps was achieved with 64 byte frames. All frame sizes were forwarded without any loss at 100% line rate, except for 64-byte frames. *Figure 1* on *page 1* shows the throughput and forwarding rates achieved from these tests.

Layer 3 IPv4/IPv6 Performance

Layer 3 load testing was also conducted, for the same range of packet sizes, to determine the maximum switching capacity and packet forwarding rates for Layer 3 IP packets without any loss. IPv4 throughput was notably better than for IPv6, especially for 256-byte packets. For IPv4, all packets were forwarded at 100% line rate, except for 64-byte packets. For the Layer 3 IPv6, packets of all sizes were forwarded at 100% line rate, except for 78-byte and 256-byte packets. The switching throughput and forwarding rates achieved in the Layer 3 unicast tests are shown in *Figure 2* on the next page.

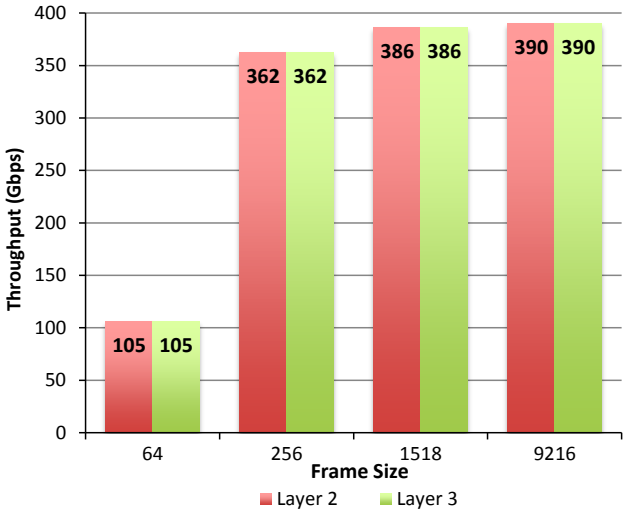
Figure 2: Catalyst 4500E Supervisor Engine 8-E, Layer 3 IPv4/IPv6 Unicast Performance



Source: Miercom, January 2015

Same as Layer 2 performance. *Maximum switching and forwarding rates with zero packet loss are shown for Layer 3 IPv4 and IPv6 bi-directional unicast traffic. Performance for Layer 3 IPv4 and Layer 2 packet handling are virtually the same.*

Figure 3: Catalyst 4500E Supervisor 8-E L2 and L3 Multicast Throughput



Source: Miercom, January 2015

One to many. *Multicast throughput performance by the Supervisor Engine 8-E for traffic through the Catalyst 4500E is nearly identical for Layer 2 and Layer 3 traffic.*

Layer 2/3 Multicast Performance

Multicast performance was measured for Layer 2 and Layer 3 traffic per the RFC 3918 IP Multicast benchmarking specification. These tests were also conducted using the same range of frame sizes: 64-, 256-, 1518- and 9216-bytes.

Multicast distribution of packets, from one ingress port to 391 egress ports, could be handled by the Catalyst 4500E Supervisor Engine 8-E at 100% line rate for all packet sizes, except for 64-byte packets. These tests run with 1 to 200 multicast groups demonstrated identical results. Multicast throughput results for Layer 2 and Layer 3 traffic were nearly identical. *Figure 3* shows the multicast throughput results.

Latency

Average latency – the time it takes a packet to traverse the switching system, in the absence of congestion and queuing – was also measured. The Catalyst 4500E Supervisor Engine 8-E delivered consistent, predictable and low latencies for all tests. Average latency results for all packets and traffic types are shown in *Figure 4* on the next page.

Key Features Exercised, Verified

Miercom engineers also exercised and verified the functionality and performance of the most popular features supported on the Catalyst 4500E switch through the Supervisor Engine 8-E.

The most impressive and significant features tested and exercised included:

- 9000W Power supply and Power-over-Ethernet scale
- High Availability features such as ISSU, SSO and VSS
- Packet captures with embedded Wireshark
- Traffic monitoring with Flexible NetFlow
- Service Discovery Gateway

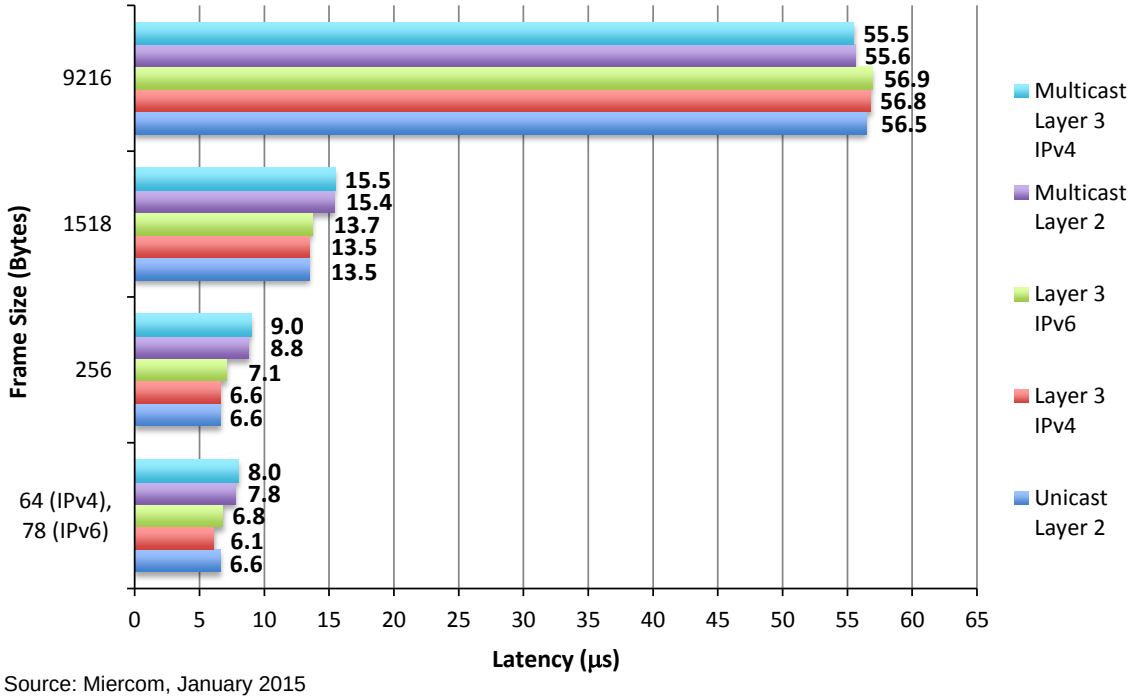
9000W Power and UPoE

Universal Power over Ethernet (UPoE) is a Cisco innovation that enables Cisco Catalyst 4500E to provide up to 60W of power over Cat5e cable, enabling a broad range of devices to be powered – from flat-panel monitors to LED data-center lighting. Cisco has been working with numerous third-party vendors to develop an ecosystem of UPoE capable devices that can be powered, controlled and monitored by the Catalyst 4500E switch.

The 9000W Power Supply

Among the latest Cisco power innovations is the 9000-watt power supply for the Catalyst 4500E switching system. 9000-watt power supply is an AC power supply with three input circuits. Catalyst 4500 series switches support one power supply and an optional redundant power supply. Each AC power supply has individual power cord and status LEDs. Systems with redundant power supplies share the load, with each unit providing approximately half of the total power. Two of these power supplies can be deployed within the Catalyst 4500E chassis and configured as either "combined" (load shared) or "redundant" (standby failover). Tests were performed with 220V of input power to all 3 inputs of each power supply and the 9000W power supply delivered **7500**W of PoE power in redundant mode. This power is sufficient to power PoE devices as shown in *Table 1* on *page 5.*

Figure 4: Catalyst 4500E Supervisor Engine 8-E Latency



Source: Miercom, January 2015

The new Catalyst 4500E Supervisor Engine 8-E delivers consistent low latency at all frame sizes for both Layer 2 and Layer 3 traffic, unicast as well as multicast.

Table 1: Maximum Number of PoE/PoEP/ UPoE Devices Supported when Using Power Supplies in a 1 + 1 Mode

Voltage	Inputs	Max PoE (15W) Devices	Max PoEP (30W) Devices	Max UPoE (60W) Devices
220 V	Triple	384	235	117

As part of the High Availability testing, a Catalyst 4500E switch was configured with two redundant power supplies and high-speed data was delivered through the switch. One of the power supplies was then turned off. Upon failure of one of the two active power supplies sharing load, the working power supply was able to provide uninterrupted power without any downtime. This makes the switch highly available in the event of single power supply failure.

Zero-configuration (Service Discovery Gateway)

Zero-configuration technologies provide a means of automatic configuration in dynamic network environments where devices are added and removed frequently, thereby eliminating the need for manual intervention and special configuration servers. Apple Bonjour is an example of a zero-configuration technology that uses the mDNS capability to locate devices and the services that the devices offer. The issue with practically all zero-configuration networking approaches is that they offer such services only across a single L2 domain, which restricts the use of a resource-advertising service to only that one network domain. The Cisco Zero-configuration solution overcomes this limitation by listening to service announcements on all configured Layer 2 network segments and building a cache of services and their corresponding addresses. It can then be configured to proxy these requests to other segments and apply filters based on various service attributes to limit which services will be seen or allowed to be advertised.

The Cisco Catalyst 4500E Supervisor Engine 8-E ships with the Cisco Zero-configuration solution. The Cisco Zero-configuration feature on the Supervisor Engine 8-E was tested with a test setup comprising of a wired MacBook client and an Apple TV that were connected on different VLANs. The Apple TV device, connected to a monitor, was used to stream a movie playing on the MacBook. Without the Cisco Zero-configuration functionality being enabled on the Catalyst 4500E, the MacBook did not discover the Apple TV and hence the content did not stream to the Apple TV monitor. However, once the Cisco Zero-configuration functionality was enabled on the Supervisor Engine 8-E, the MacBook was able to discover the Apple TV and the content could be seen on the Apple TV monitor instantaneously.

Similarly, the Cisco Zero-configuration feature can also be used to advertise printer services across different VLANs to enable clients in different VLANs to access these printer services.

High Availability

The Supervisor Engine 8-E supports numerous high availability features to ensure that the Cisco Catalyst 4500E switching system continues to move data, no matter what.

We tested the following High Availability features on the Catalyst 4500E system with Supervisor Engine 8-E:

SSO - Stateful Switchover

ISSU – In-Service Software Upgrade

VSS – Virtual Switching System

In addition to these features, the Supervisor Engine 8-E also provides other high availability features such as Nonstop Forwarding (NSF) for Layer 3 forwarding and redundant power supplies for power outage redundancy (already tested with the 9000W power supply in the preceding section).

Stateful Switchover (SSO)

Stateful Switchover (SSO) enables high availability and redundancy on the Catalyst 4500E system by allowing a redundant supervisor engine to quickly take over operation of the switch if the active supervisor engine fails. When a redundant supervisor engine runs in SSO mode, it starts up in a fully initialized state and synchronizes with the persistent configuration and the running configuration of the active supervisor engine. It maintains the state of SSO client protocols. All changes in hardware and software states for features that support SSO are kept in sync. Consequently, it offers zero interruption to Layer 2 sessions in a redundant supervisor engine configuration.

The stateful switchover setup

To exercise SSO, a Catalyst 4500E switch with dual Supervisors, and with line cards sending bi-directional Layer 2 traffic across the switch, was first configured. One of the Supervisors was acting as the Active Supervisor, performing all the processing. The other Supervisor in the switch was the Standby Supervisor. On removing the Active Supervisor from the switch, the Standby Supervisor resumed traffic within 14 milliseconds, keeping the switch up and forwarding traffic all the time, providing undisrupted voice and video delivery.

In-Service Software Upgrade (ISSU)

In-Service Software Upgrade (ISSU) allows Catalyst 4500E switch customers to virtually eliminate planned outages for full feature software upgrades. It provides the means to upgrade or, if necessary, downgrade Cisco IOS Software in a redundant Cisco Catalyst 4500E system without incurring a service outage by building on the Stateful Switchover (SSO) feature. ISSU is a user-initiated and user-controlled process. It is carried out through a set of executive-level CLI commands issued in a specific order to upgrade/ downgrade a Cisco IOS Software Image running on a Cisco Catalyst 4500E supervisor engine configuration.

To perform ISSU, we again used the Catalyst 4500E switch with dual Supervisor and line cards sending bi-directional Layer 2 traffic across the switch. Then we upgraded the Standby Supervisor with the newer version of Switch software and executed ISSU commands through the Command Line interface. The ISSU software upgrade was observed and switchover to the newer version software was clocked at just 13 milliseconds.

Virtual Switching System (VSS)

The Cisco Virtual Switching System (VSS) is a clustering technology that pools two Cisco Catalyst 4500E switches into a single virtual switch. In a VSS, the data plane of both clustered switches is active at the same time on both chassis. VSS members are connected by virtual switch links (VSL) using standard Gigabit or 10 Gigabit Ethernet connections between the VSS members. VSL can carry regular traffic in addition to the control plane communication between the VSS members. In addition to high availability in case of link or network device failure, VSS also enables better load balancing and eliminates the need for spanning tree with Layer 2 Multichassis EtherChannel (MEC) between access and distribution as well as reduces touch points with a single management and control plane between two switches, among other benefits.

For testing VSS, we configured two Catalyst 4500E switches in a Virtual Switching System (VSS) configuration. In VSS one Supervisor Engine 8-E is in active control of two switches, though another redundant Supervisor 8-E in the VSS standby switch is prepared to take over. In the case of an active switch failure, the standby Supervisor 8-E assumed full operations of L2 traffic in less than 205 milliseconds. The testing of VSS included failure of a link, data paths through different switches, and failure of the active VSS switch.

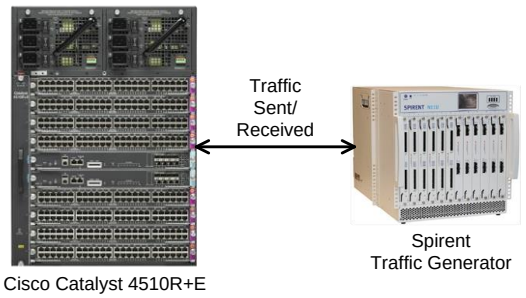
Flexible NetFlow

In addition to being the foundation for traffic monitoring and accounting, Flexible NetFlow is an enabler of security and troubleshooting tools using which IT can detect network anomalies, perform troubleshooting on network issues, and locate network bottlenecks for targeted investments. Cisco partners with a large number of third party vendors to provide rich applications built on Flexible Netflow. Traditional Netflow supported pre-defined keys (set of fields in the packet) that could be used to collect information. However, with Flexible Netflow, users can define their own keys.

Using Flexible NetFlow on Supervisor Engine 8-E, customers can track a larger amount of information by selecting traffic flows to capture or monitor based on 30 different elements of header information. These include source or destination MAC address, IP address, VLAN ID or priority, protocol, DSCP or precedence, length, and TCP source or destination port.

The Cisco Catalyst 4500E Supervisor 8-E provides 128K Flexible NetFlow entries. In the test configuration, we were able to capture 128K

Test Bed Diagram
Performance Test Setup



flows in Flexible NetFlow and exported it to a collector. We used the Plixer scrutinizer-flow-analyzer to capture Flexible NetFlow flows from the Catalyst 4500E Supervisor 8-E and perform analysis to inspect details of individual flows.

Onboard Packet Analyzer (Wireshark)

Wireshark is a popular packet analyzer application that network administrators use for network troubleshooting and analysis. The Supervisor Engine 8-E includes onboard Wireshark application that allows an administrator to perform a packet capture and perform detailed analysis on the switch itself. Wireshark runs on its own core processor and can decode and display up to eight flows concurrently.

To examine this feature, we configured 8 concurrent capture start points on different interfaces and began capture of packets with each flow using buffer of 1,000 packets, with data traffic also running through the switch. The switch was configured to save the packets to 8 individual .pcap files on the switch boot flash. The file created by the Wireshark utility was the standard file in .pcap format, which could be exported and viewed using the standard Wireshark application on a PC.

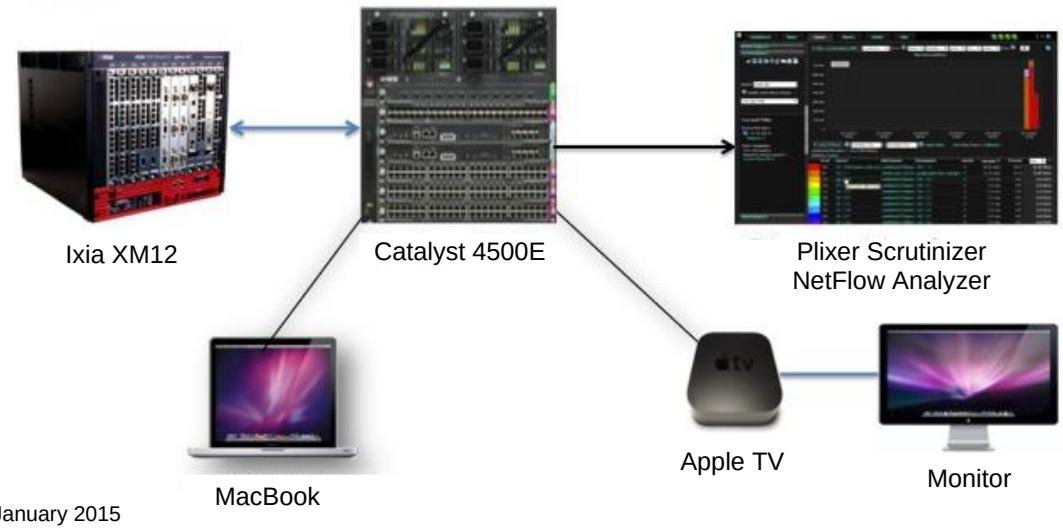
A summary of the standard .pcap file could be displayed directly on the Catalyst 4500E, and also a frame-by-frame detailed analysis of the capture could be viewed. With these 8 Wireshark sessions, we observed that the CPU load was at a maximum of 25% utilization with other background traffic running. This leaves enough CPU horse power to easily run other features on the Catalyst 4500E.

Bottom Line

Testing confirmed the Catalyst 4500E Supervisor Engine 8-E's impressive performance and consistent low latency. Testing also verified that the new Supervisor Engine 8-E supports key features including advanced high-availability capabilities and rich troubleshooting and monitoring features. The new 9000W power supply also provides unprecedented UPoE/PoE+ scale.

The Supervisor Engine 8-E continues in the Cisco Catalyst 4500E platform's tradition of unparalleled performance, high resilience to failures, and cutting edge innovation such as Converged Access, Service Discovery Gateway. Cisco TrustSec, uplink MACSec, Virtual Switching System, Wireshark and Flexible Netflow.

Test Bed Diagram
Features Test Setup with Dual 9000W Power



Source: Cisco, January 2015

How We Did It

For switch performance testing, the test bed was configured with 384 GigE ports and 8 TenGig ports of traffic being delivered by the Spirent test system to the Cisco Catalyst 4510R+E. The Catalyst 4510R+E chassis was configured with 8 WS-X4748-RJ45V+E line cards, two 6000W power supplies, and Cisco Catalyst Supervisor Engine 8-E , running Cisco IOS XE Software Release 3.6.0E - 15.2(2)E. The Spirent system delivered traffic to the switch in accordance with RFC 2544 for Unicast flows, and RFC 3198 for Multicast.

For feature functionality and high availability, a Catalyst 4507R+E switch was configured with dual Supervisor 8-E, 2 WS-X4748-UPOE+E line cards, 1 WS-X4724-SFP-E line card and dual 9000W power supplies with 3 inputs of 220V on each power supply. This test bed was connected to Ixia XM12 chassis (www.ixiacom.com) with GigE modules sending bidirectional traffic to the Catalyst 4507R+E. The Ixia hardware was configured with IxOS version 6.10.750.5 EA, IxNetwork 6.0.400.22 EA-Patch1, and IxAutomate 7.0.110.5 GA.

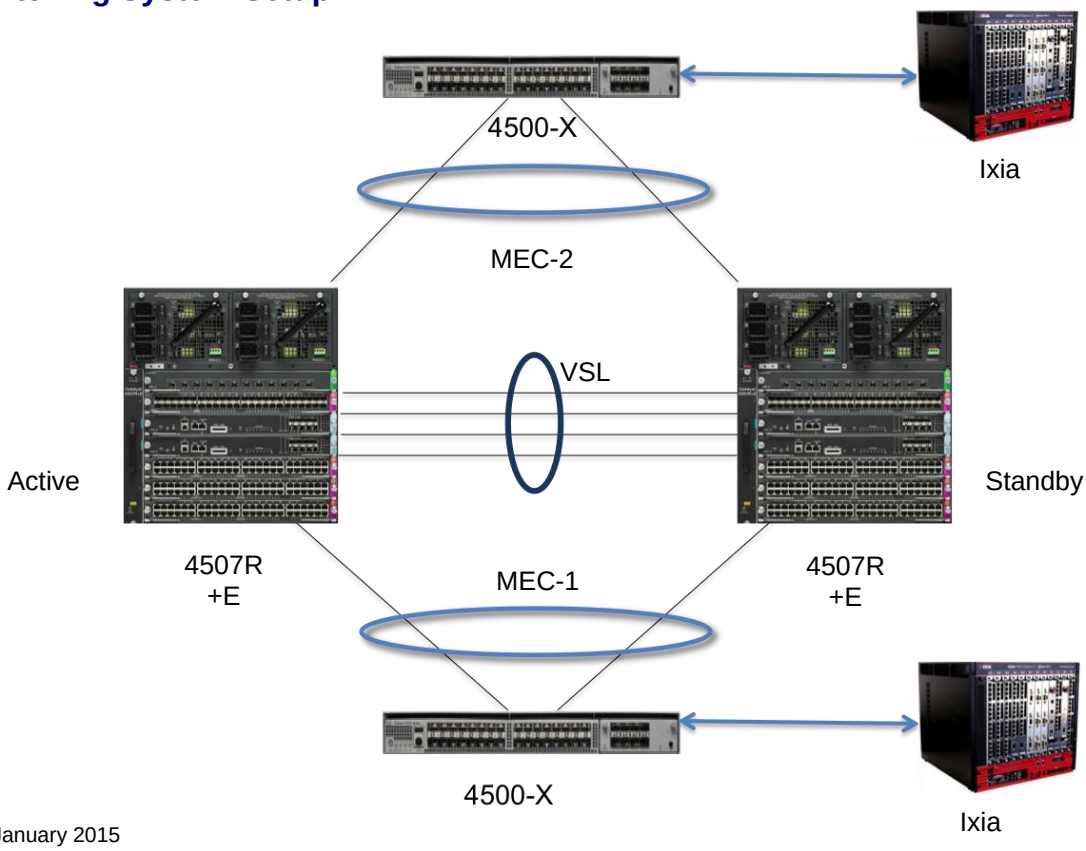
A Mac laptop and an Apple TV connected to an LCD monitor were used for Zero-configuration (Service Discovery Gateway) testing. A PC running the Plixer Scrutinizer flow monitor was connected to one of the GigE port for capturing and displaying the Flexible Netflow information.

For Virtual Switching System (VSS) high-availability testing, the test bed shown in the diagram below was used. An Ixia XM12 chassis (www.ixiacom.com) with GigE modules sent bidirectional traffic through the VSS configuration and carefully measured loss during failover tests. The Ixia hardware was configured with IxOS version 6.10.750.5 EA, IxNetwork 6.0.400.22 EA-Patch1, and IxAutomate 7.0.110.5 GA.

The tests in this report are intended to be reproducible for customers who wish to recreate them with the appropriate test and measurement equipment. Contact Miercom Professional Services via reviews@miercom.com for assistance. Miercom recommends customers conduct their own needs analysis study and test specifically for the expected environment for product deployment before making a product selection. Miercom engineers are available to assist customers for their own custom analysis and specific product deployments on a consulting basis.

Test Bed Diagram

Virtual Switching System Setup



Source: Cisco, January 2015

Miercom Performance Verified

In tests conducted of the Cisco Catalyst 4500E Supervisor 8-E, Miercom confirmed its superior performance, high availability, Flexible NetFlow and Wireshark traffic-analysis capabilities, and UPOE scale, making it an ideal platform for campus access networks.

With proven high performance, consistently low latency and rich feature set, Cisco's Catalyst 4500E switching system, driven by the Supervisor Engine 8-E, has earned Miercom's Performance Verified Award.

Catalyst 4500E
Supervisor Engine 8-E

Cisco Systems, Inc.
170 West Tasman Drive
San Jose, CA
1-800-553-6387
www.cisco.com

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