Comparative Analysis:
Cisco Catalyst 4500E
Brocade FastIron SX 1600

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i. Executive Summary

Miercom was engaged to conduct a comparative testing of two high-capacity L2 and L3 network switches: the popular Cisco Catalyst 4500E, and a comparably configured, competitive switch, the FastIron SX 1600, from Brocade Communications Systems.

Miercom executed comprehensive hands-on testing and evaluated the performance of some widely deployed features that are critical for reliable functioning of enterprise networks.

The test methodology was developed that was designed to examine various aspects of the switches. The switches were tested side-by-side in September 2014.

This report summarizes the results of the testing in these areas:

- Switching-fabric survivability
- Throughput between 48-port line cards for bi-directional full-load streams between modules
- Ability to handle data bursts without dropping packets
- IPv6 Forwarding Information Base capacity

Miercom found that with better data plane redundancy, burst handling, and line-rate, no-loss throughput between high-density line cards, the Cisco Catalyst 4500E demonstrated superior performances against the Brocade SX 1600.

Key findings from Miercom's comparative testing of the Cisco Catalyst 4500E and the Brocade FastIron SX 1600

Data Plane Redundancy	Tests confirmed that the centralized switch fabric in either of Cisco's Supervisor 8-E modules can maintain full line-rate data flows between switch ports if one of the supervisors fails. However, if one of Brocade's Switch Fabric Modules fails, throughput between line cards drops by half.
Throughput between Line Cards	Testing found the Cisco Catalyst 4500E delivered full-line-rate, bi-directional throughout between all ports on two 48-port Gigabit Ethernet (GE) line cards – 96 Gbps total – with no loss. The Brocade SX 1600 dropped half of the full-load traffic between two 48-GE-port line cards.
Maximum Burst Size with No Loss	The Cisco switch can accommodate data bursts about six times larger than the Brocade SX 1600, with no packet loss.
Maximum Routing-Table Capacity	Both switches can handle the maximum number of routes specified in their respective datasheets, tests showed. The Cisco Catalyst 4500E supports twice the number of IPv6 routes (128K) than does the Brocade SX 1600 (64K).

Miercom has independently verified key performance differences between the Cisco Catalyst 4500E and the Brocade SX 1600. With better fabric survivability, burst handling, and line-rate, no-loss throughput between high-density line cards, the Cisco Catalyst 4500E is awarded ***Miercom Performance Verified*** as a result of this comparative switch testing.

Robert Smithers

CEO

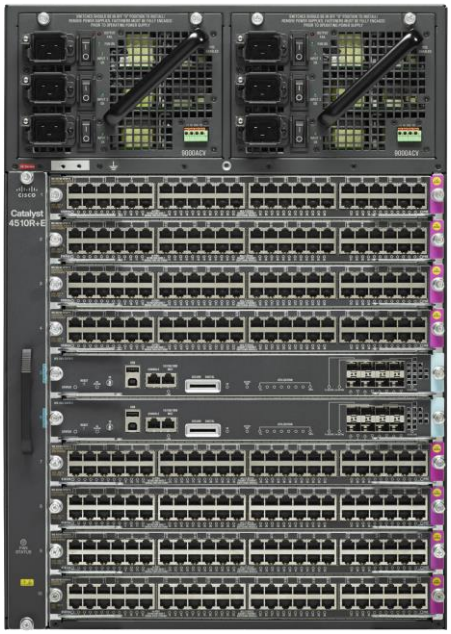
Miercom

ii. About the Products Tested

The switches that were comparatively tested are both modular, high-capacity, Layer 2 and Layer 3 switches, which can serve in access, aggregation or core roles depending on modules and configuration.

Cisco

The Cisco switch tested was the Cisco Catalyst 4500E, pictured below.
The 10-slot switch is the high-end model of the vendor's popular Catalyst 4500E series. Two slots in the center (slots 5 and 6) are designed and reserved for two fully redundant Supervisor modules. The latest Supervisor Engine 8-E was employed in the testing. The Cisco switch in our testing ran IOS-XE 0.3.6.0E (IOS version 15.2(2)E).



***Cisco Catalyst 4500E**, shown here fully loaded with eight 48-port Gigabit Ethernet (copper) line cards.*

The 24-inch-high (14 RU) Catalyst 4500E chassis weighs in at 55 pounds empty. Eight slots accommodate line cards, and the vendor offers a rich assortment of about 20 different line cards, varying in speed, number or ports and media (copper or fiber).

Cisco Catalyst 4500E switch with 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 Cisco Catalyst 4500E switch was configured with the following modules:

Slot	Number Ports	Description	Model
1	48	10/100/1000BaseT UPoE E Series	WS-X4748-UPOE+E
2	48	10/100/1000BaseT UPoE E Series	WS-X4748-UPOE+E
3	24	1000BaseX SFP	WS-X4724-SFP-E
4	24	1000BaseX SFP	WS-X4724-SFP-E
5	8	Supervisor 8-E, 10GE (SFP+), 1000BaseX (SFP)	WS-X45-SUP8-E
6	8	Supervisor 8-E, 10GE (SFP+), 1000BaseX (SFP)	WS-X45-SUP8-E

The configuration remained the same for the testing although, as detailed in the following test sections, different modules played a starring role in different tests.

Brocade

The Brocade switch tested was the FastIron SX 1600, running software version 07.4.00fT3e3, the high end of the vendor's FastIron SX series of L2/L3 switches. The chassis, pictured below, consists of two rows, each accepting up to eight interface modules, for a total of 16 line-interface slots. In the middle are slots for two fabric modules. The vendor offers about 16 different interface modules. The Brocade switch can also be deployed in access, aggregation or core roles, depending on modules and configuration.

Brocade FastIron SX 1600 *features two chassis rows, each row accommodating eight interface cards and a fabric module.*

Brocade offers a high-density, 48-port Gigabit Ethernet (GE) module, which uses two vertical slots. Two of these were employed in our testing. Most of the vendor's other interface modules take just one of the 16 interface-module slots.

Depending on configuration, Brocade says the FastIron SX 1600 can deliver up to 384 Gigabit Ethernet ports, or up to 132 x 10GE ports (SFP+).

The Brocade SX 1600 switch tested was configured with the following modules:

Slot	Number Ports	Description	Model
F1	--	Switch Fabric Module	SX-FISF
F2	--	Switch Fabric Module	SX-FISF
S1	24	Gigabit Ethernet Fiber	SX-FI-24HF
S2	48	Gigabit Copper + PoE+	SX-FI-48GPP
S9	0	Management module	SX-FIZMR6
S10	0	Management module	SX-FIZMR6
S16	48	Gigabit Copper + PoE+	SX-FI-48GPP
S17	24	Gigabit Ethernet Fiber	SX-FI-24HF

The Brocade configuration remained the same for the testing although, as detailed in the following test sections, different modules were involved in different tests.

iii. Test Bed Setup

All tests of the Cisco and Brocade switches employed the same Ixia test system: IxNetwork software controlling test modules in a 12-slot Ixia XM12 chassis. Each switch was tested as a standalone unit directly connected to the Ixia XM12 Test System.

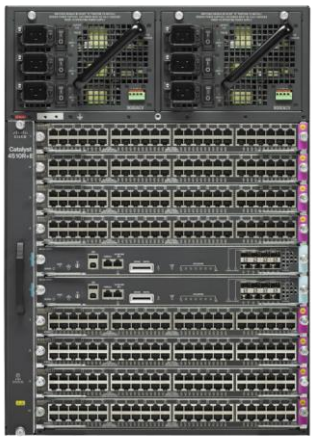
The Ixia XM12 chassis was used with the Ixia Network application as the primary traffic generator that drove network traffic through the switches using a vast library of test methodologies. Ixia (www.ixiacom.com) is an industry leader in performance testing of networking equipment. Ixia's exclusive approach and comprehensive set of online open source test methodologies makes Ixia a clear choice for testing L2-L7 based networking products.

OmniPeek, a portable network analyzer from WildPackets (www.wildpackets.com) was used for the testing. The OmniPeek has an intuitive graphical interface for analyzing and troubleshooting enterprise networks. Managing and monitoring network performance is handled by real-time observation of network statistics, such as application vs. network latency, aggregating multiple files and exact drill-down to packets using an interactive dashboard. Problems can be analyzed and fixed across network segments, including those at remote offices.

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.

Switch under Test

Cisco Catalyst 4500E



Ixia Test System

XM12 multi-slot chassis with:

- IxNetwork software
- Copper and Fiber GigE modules

Bi-directional traffic

Ixia XM12

Switch under Test

Brocade FastIron SX 1600

Ixia XM12

Bi-directional traffic

Source: Miercom, November 2014

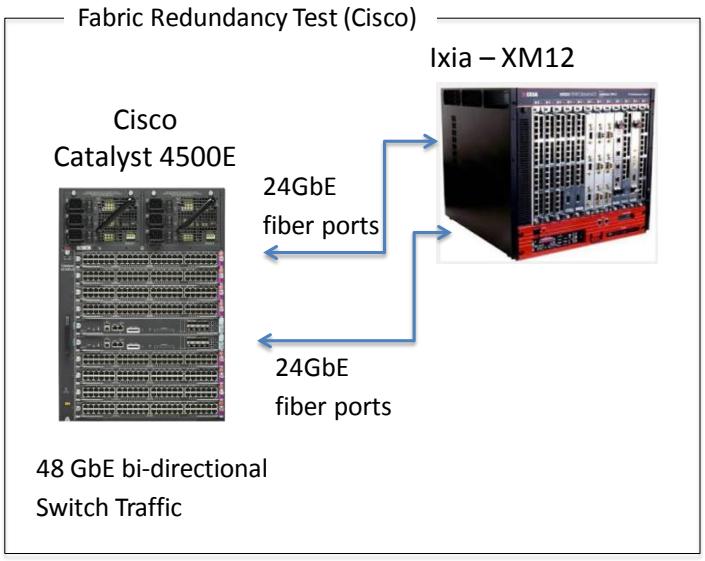
1.0 Data Plane Resiliency Test

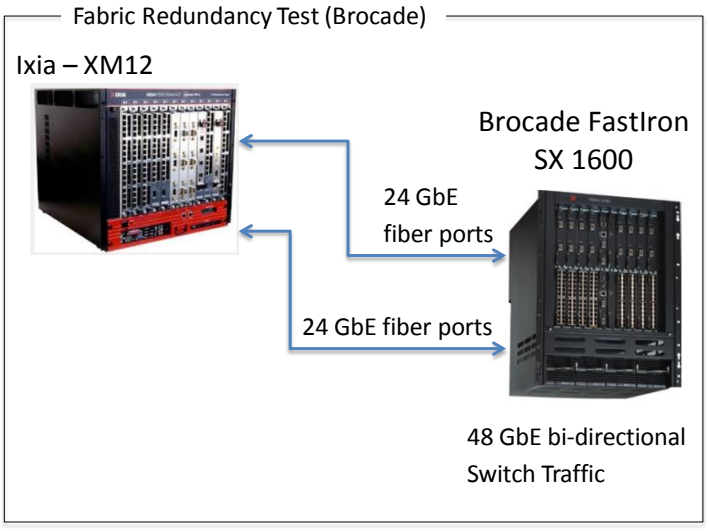
Test Objective

To simulate the case where a key fabric module fails. Ideally, one of the two switch fabric modules can fail, with little or no impact on user traffic traversing the switch.

How We Did It

The Cisco and Brocade switches each had two 24-port fiber Gigabit Ethernet modules. The switches were tested one at a time, first Cisco and then Brocade. First 24 connections were made from the Ixia test system to the ports on one of the 24-port fiber GE modules in the switch. Then 24 more fiber GE connections were made from the switch's other 24-port fiber GE module to ports on the Ixia test system, as shown in the below diagrams.





The switch was configured first for Layer 2 traffic. The switch was set up so that all traffic delivered on one port would be switched to the same egress (exit) port, and vice versa for traffic in the other direction – in a one-to-one, port-to-port relationship.

The test system then delivered data, bi-directionally, on all 48 ports. The first test round was short, 64-byte packets. The traffic switching performance was measured using the RFC 2544 test available in Ixia. Once the test finished execution, one of the Supervisor modules (fabric module in the case of Brocade) was intentionally dislodged. The same RFC 2544 test was then run again and the resulting impact on the traffic flows was observed.

The same process was repeated with increasingly larger packet sizes, up to 1,518 bytes. The exact throughput levels before and after the fabric-module interruptions were noted.

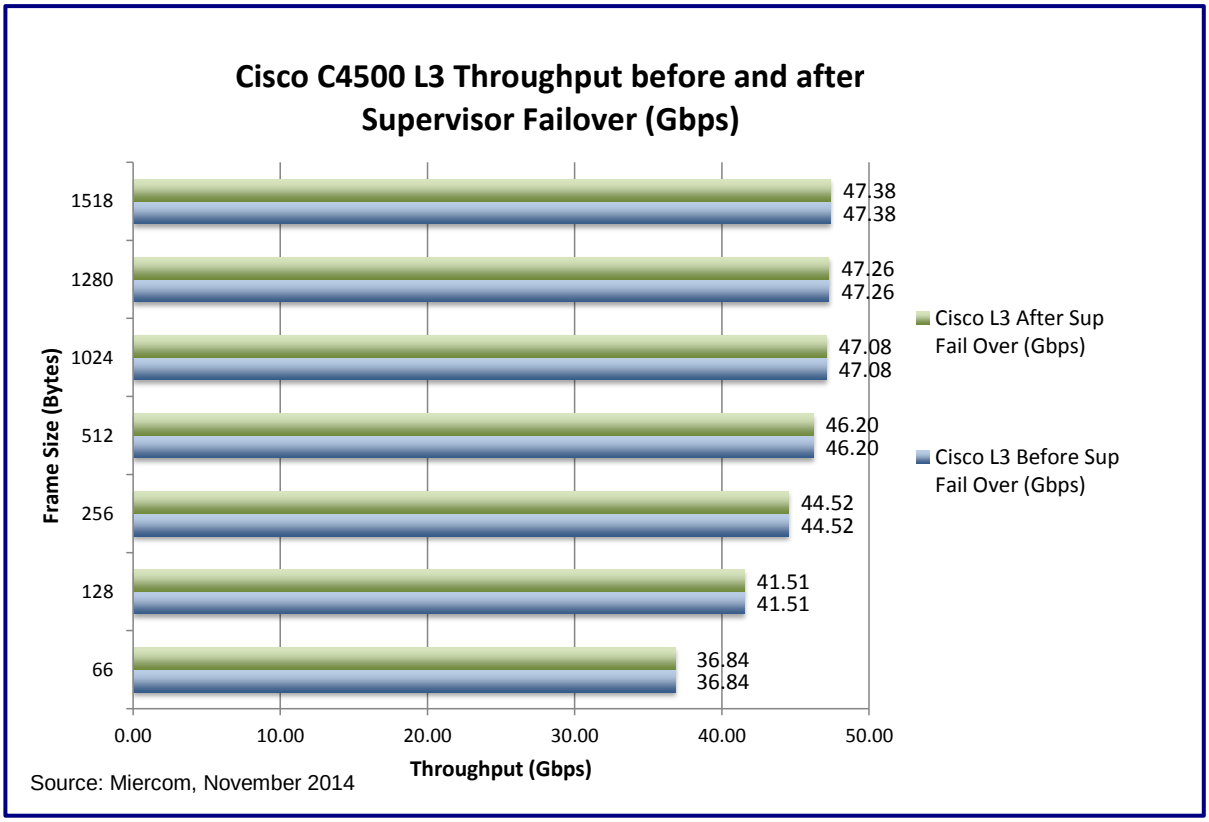
After the series of tests was completed with Layer 2 switching, the switch was appropriately reconfigured and the process was repeated with Layer 3 IP (v4) forwarding with the traffic performance being measured using the RFC 2544 test available in Ixia.

When testing of the Cisco switch was completed, the entire test series was executed again with the Brocade switch.

Result Summary

"Throughput with the Cisco Catalyst 4500E remains unchanged after a Supervisor Engine 8-E fails. There was no lost data or any reduction of switch-fabric capacity."

The chart shows the Cisco throughput, before and after the active Supervisor Engine module fails. The Supervisor controls and manages the switch fabric.

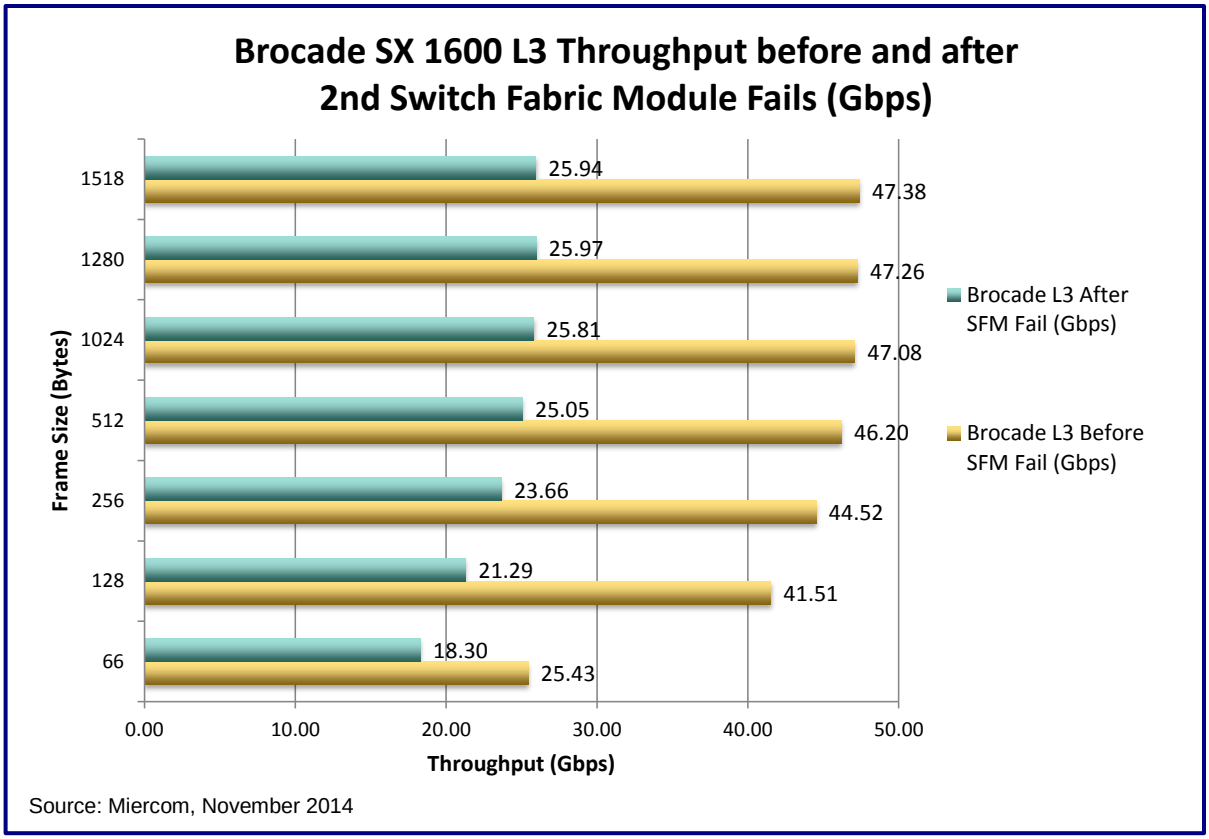


Source: Miercom, November 2014

The chart reflects the Cisco results with Layer 3 forwarding. As it turns out, the Layer 2 and Layer 3 throughputs are nearly identical, for both Cisco and Brocade.

What is noteworthy is that throughput with the Cisco 4500E remains unchanged after a Supervisor Engine 8-E fails. There was no lost data or any reduction of switch-fabric capacity.

The chart on the following page shows the same L3 results for the Brocade FastIron SX 1600.



Source: Miercom, November 2014

Except for very short packets, where the Cisco switch forwards quite a bit more, the throughputs for all other packet sizes are very similar between the Cisco and Brocade – until a fabric module fails.

With the failure of a Switch Fabric Module (SFM), traffic through the Brocade switch drops considerably – 45 to 50 percent for most packet sizes.

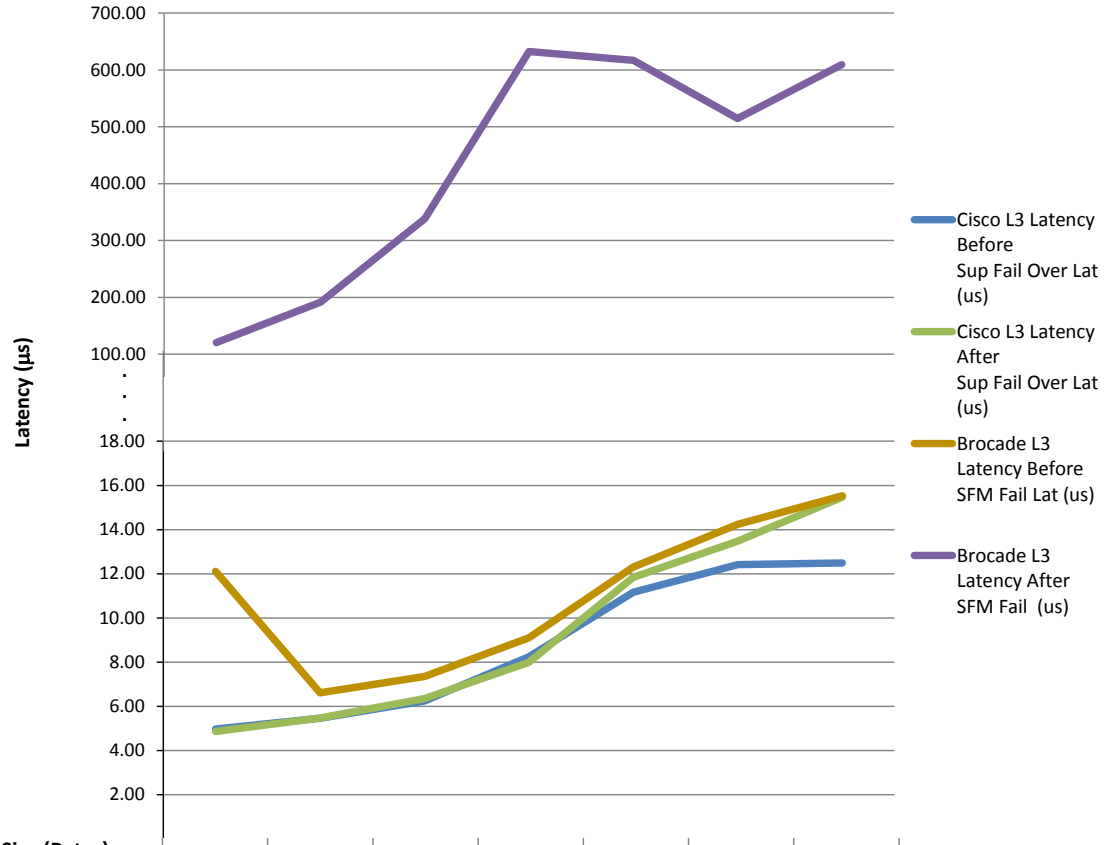
The Cisco Catalyst 4500E, on the other hand, maintains throughput unchanged after the active Supervisor failover to the standby Supervisor.

While Brocade – in its documentation and marketing materials – refers to its dual-module design as "switch fabric redundancy," however, its two fabric modules work on a load-sharing basis, and both are required to be active and running to support full switch capacity.

In Brocade's case, when one SFM fails, the switch capacity falls precipitously – nearly half of the packets are dropped.

Layer 3 Latency during Failover

"Latency of packets through the Cisco switch does not change when the Supervisor fails over. Cisco's redundant Supervisors can each fully control the switch fabric and support data transfers between all ports at line rate."



Frame Size (Bytes)	66	128	256	512	1024	1280	1518
Cisco L3 Latency Before Sup Fail Over Lat (us)	4.97	5.46	6.25	8.25	11.17	12.42	12.49
Cisco L3 Latency After Sup Fail Over Lat (us)	4.86	5.47	6.35	7.99	11.84	13.48	15.47
Brocade L3 Latency Before SFM Fail Lat (us)	12.11	6.61	7.35	9.10	12.30	14.24	15.54
Brocade L3 Latency After SFM Fail (us)	120.40	191.52	338.50	632.48	616.81	514.52	609.30

Source: Miercom, November 2014

As the chart above shows, the latencies on Cisco and Brocade switches are very similar for most packet sizes before failover. However, the latency of packets through the Cisco switch

does not change when the Supervisor failover occurs. Cisco's redundant Supervisors can each fully control the switch fabric and support data transfers between all ports at line rate.

Brocade latency, **after** the SFM failure, skyrockets as packets are buffered and discarded. The switch capacity is reduced drastically. The chart shows the latency of the Cisco and Brocade switches before and after failover.

Brocade does note the following in its FastIron SX 1600 documentation: "The two switch fabric modules in the FastIron SX 1600 operate in a load-sharing fashion. Upon failure of one of the switch modules, some system capacity will be lost. In this event, some traffic flows may experience reduced capacity through the remaining operational switch fabric during periods of high traffic loading."

2.0 Buffer Depth Capacity Test

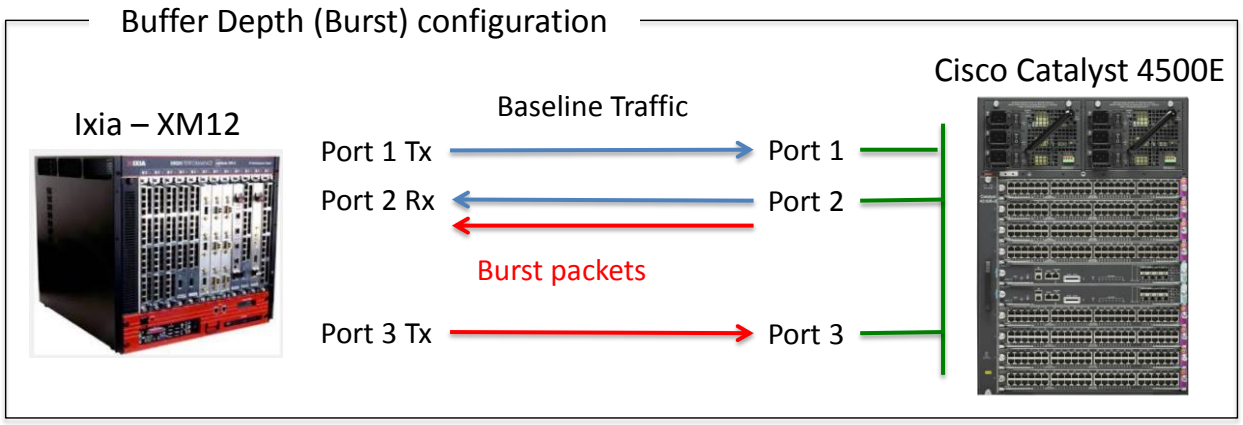
Test Objective

When an outbound port is overloaded – that is, there is more data to be sent out than the port has bandwidth to send – the result is either buffered and/or dropped packets. Such momentary events are termed data "bursts." All switches and routers have buffers to accommodate such bursts – up to a point.

The goal of this testing was to compare how well the Cisco and Brocade switches accommodate data bursts.

How We Did It

The test plan was to demonstrate the "maximum buffer burst capacity" on one port. The switch under test was configured with three active ports as shown in the diagram below. The Cisco Catalyst 4500E is shown, but the configuration of the Brocade was the same.



The Ixia test system was configured to deliver a 1-Gbps unidirectional Layer 3 traffic flow to Port 1 on the switch. This traffic stream would be forwarded to Port 2 and be delivered back out to the Ixia traffic generator. This traffic flow, called the baseline, would fully load Port 2's outbound channel. The Ixia would confirm that there was no packet loss.

Then, with the baseline traffic running continuously at line rate with no packet loss, a burst of a specific number of packets was sent from Ixia Port 3 to switch Port 3, also destined for outbound delivery via Port 2.

The number of burst packets sent was compared with the burst packets received and, if there was no loss, the burst size would be increased – until loss occurred. This process is described more in the following section.

Finding Max Bursts without Packet Loss

The best metric for measuring the buffer performance of a switch system is the "maximum burst size without packet loss." That is the amount of data – in the form of an intermittent burst – that can be accepted and handled by the system, over and above a full, steady-state background traffic load, without any packets being dropped.

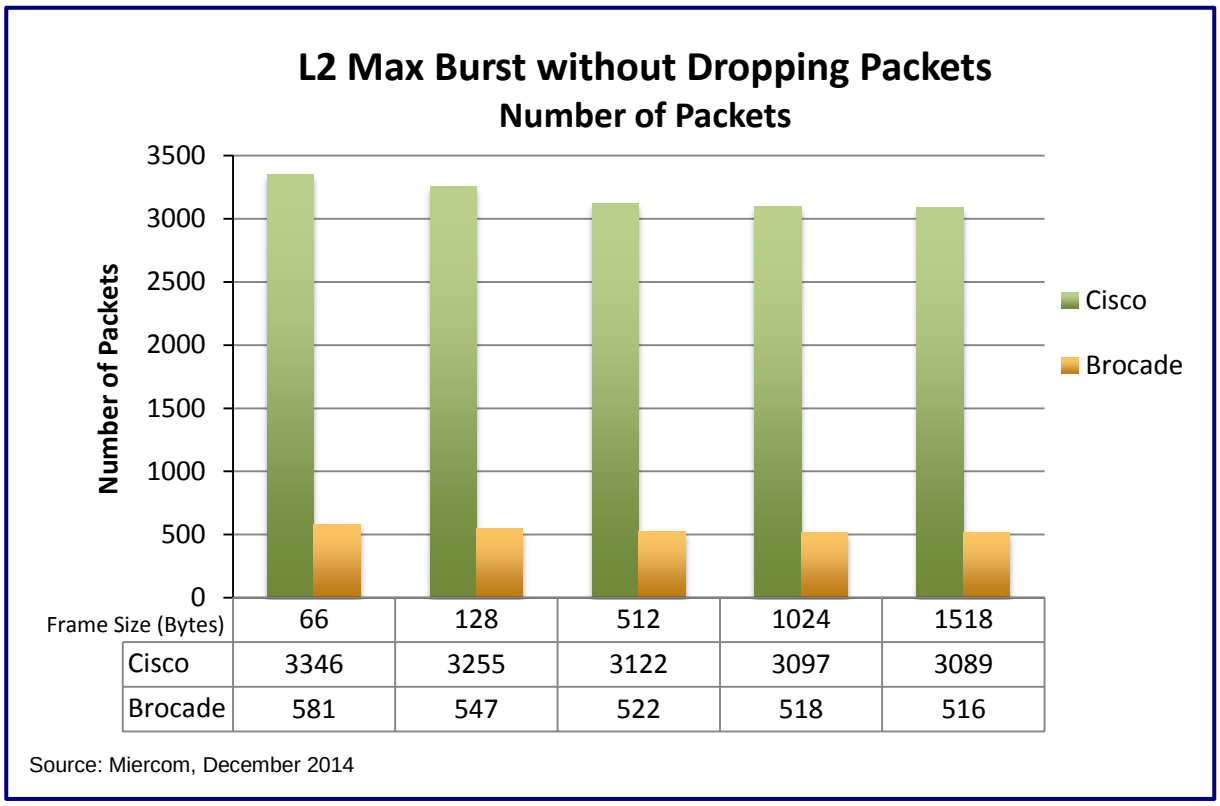
The first step in finding the max burst size is to set up a "baseline" (or background) flow. This flow fills the Gigabit Ethernet egress (exit) port buffer on a steady-state, continuous basis, with no packets dropped.

"Bursts" are then created by sending a specific number of packets, for each frame size, on a particular channel with the baseline flow running. The size of the burst is then adjusted, through repeated iterations, to find the "maximum burst size" for a particular frame size, with no packets dropped. Each burst is sent only once and any packet drops (missing packets) are noted by the Ixia system.

At the max burst size, no packets are lost, where max burst +1 results in at least one packet lost. After multiple iterations, it was determined that for 128-byte packets, the Cisco Catalyst 4500E could accommodate a maximum burst size of 3,255 packets for a single port as compared to only 547 packets on Brocade SX 1600 for a single port.

Results and Analysis

"The Cisco Catalyst 4500E handles bursts about six times greater than the Brocade SX 1600."



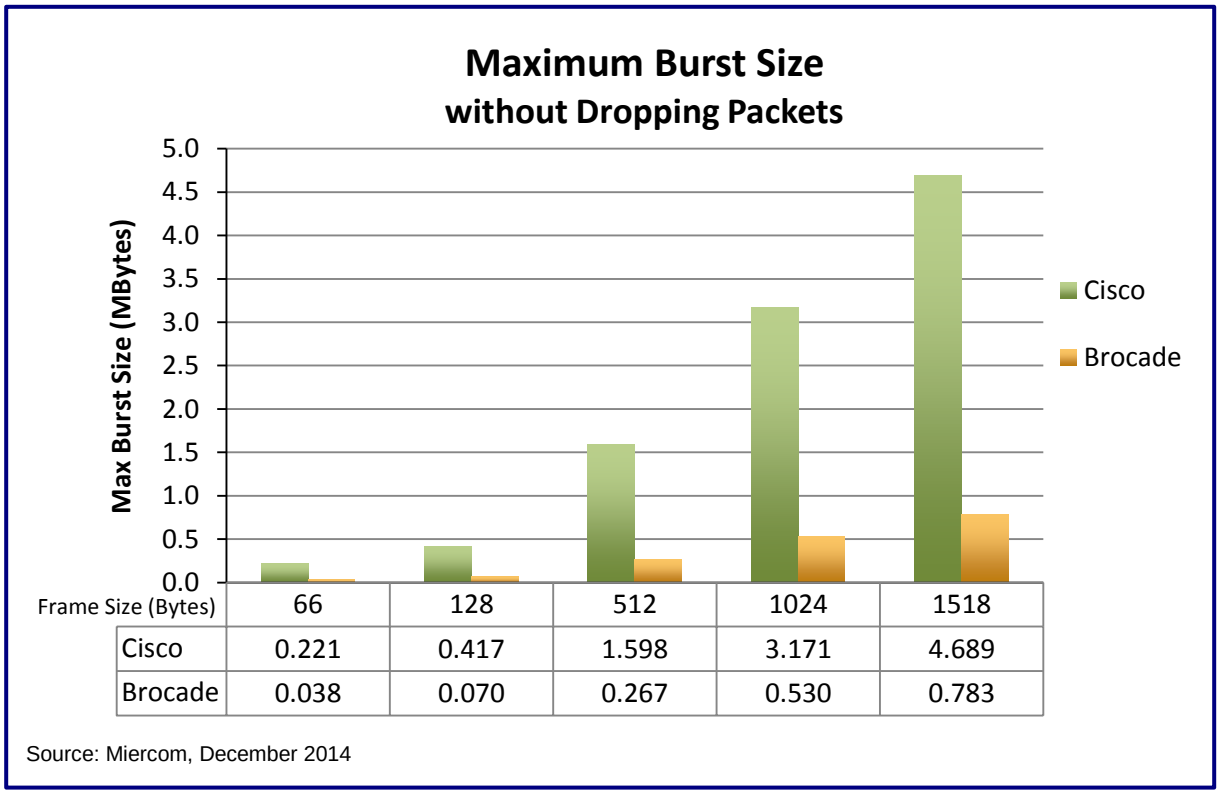
Frame Size (Bytes)	66	128	512	1024	1518
Cisco	3346	3255	3122	3097	3089
Brocade	581	547	522	518	516

Source: Miercom, December 2014

The chart above shows the max burst size of the Cisco and Brocade switches, in number of packets. It turns out the number of packets in the max burst vary little by packet size. The results show that the Cisco Catalyst 4500E handles bursts about six times greater than the Brocade SX 1600.

The following chart shows the size of the max burst, in megabytes, based on the same results.

The bottom line: The Cisco Catalyst 4500E handles traffic bursts (in Mbytes) without packet loss, at least six times larger than the Brocade SX 1600.



Frame Size (Bytes)	66	128	512	1024	1518
Cisco	0.221	0.417	1.598	3.171	4.689
Brocade	0.038	0.070	0.267	0.530	0.783

Source: Miercom, December 2014

3.0 High-Density-Card Throughput Test

Test Objective

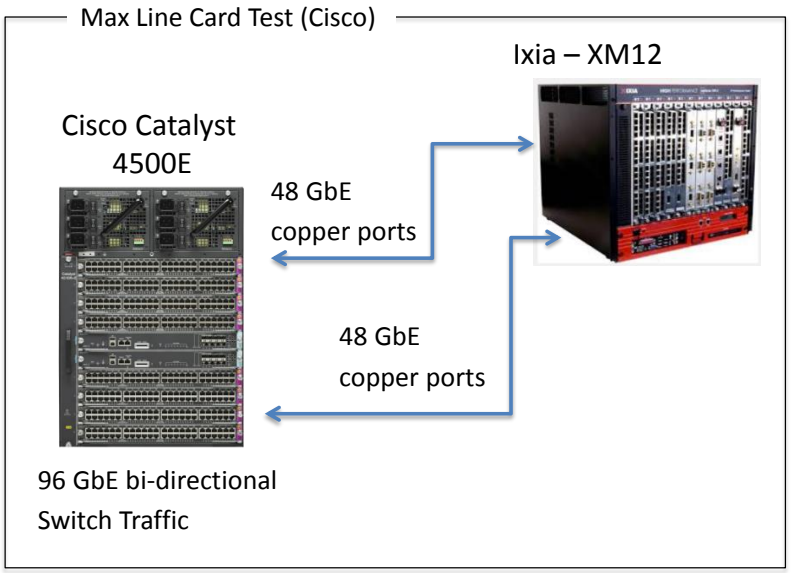
Both Cisco and Brocade offer 48-port Gigabit/s Ethernet copper line cards – currently their highest density cards – for use in their respective switches. The objective of this test was to determine whether the switch can handle full bi-directional traffic loads between two of the high-density, 48-port line cards.

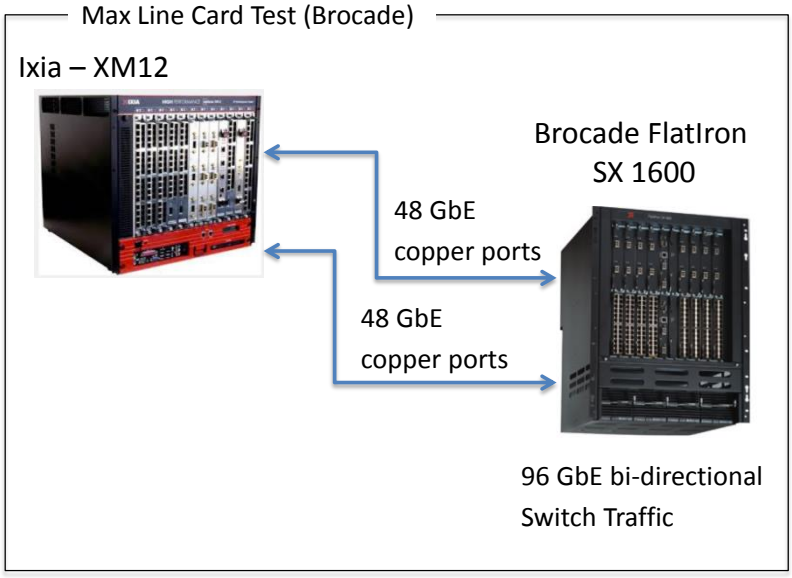
How We Did It

Both the Cisco and Brocade switches tested were configured with two 48-port, high-density GE copper line cards. As shown in the diagrams, the Ixia test system connected to all 48 GE ports on one line card via copper connections, and then via 48 more copper connections to the ports on the other line card.

Layer 3 (IPv4) traffic was then generated at line rate on all test ports, delivering 96 Gbps of traffic on all 96 switch ports. The switch under test was configured to forward traffic between port pairs – that is, traffic from an ingress port was all forwarded to the same egress (exit) port and traffic in the reverse direction followed the same return path.

Tests were run for various packet sizes, from 66- to 1,518-byte packets, and the Ixia test system carefully noted packets sent versus packets received back, the difference being packets dropped and user traffic lost.



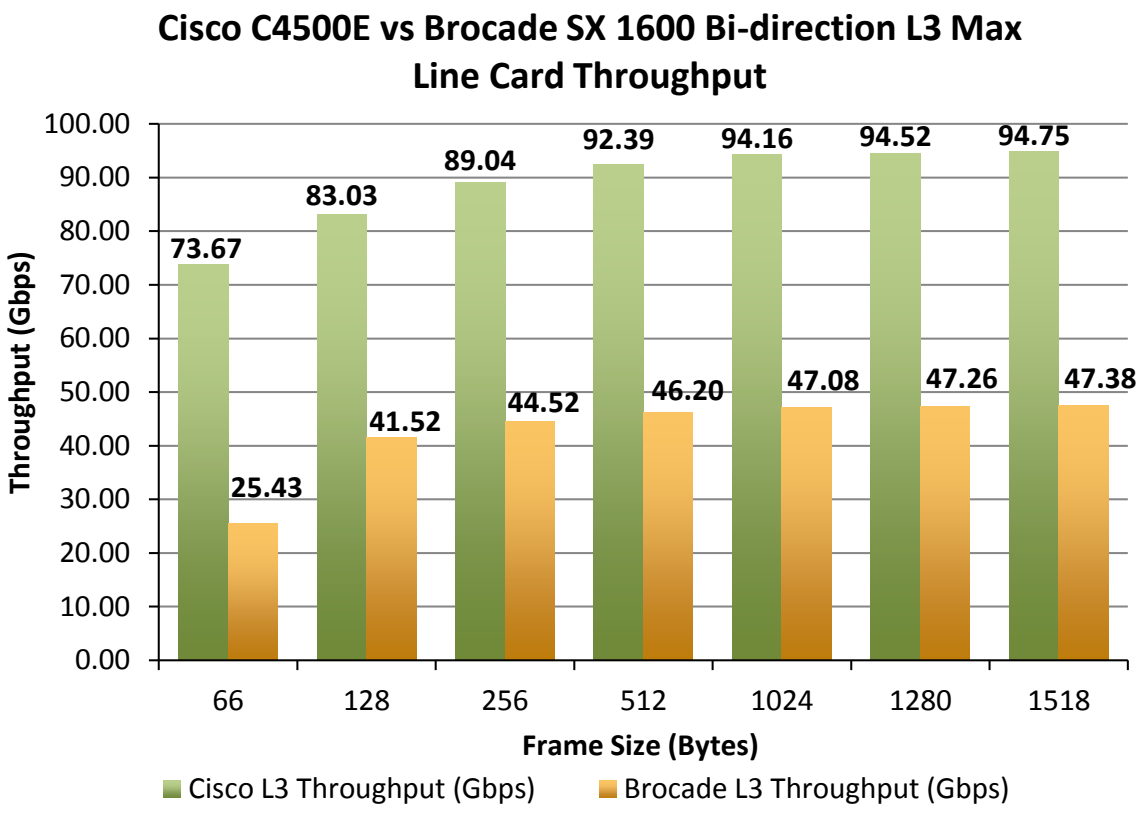


Results and Analysis

The chart below shows the results of the throughput tests between the high-density, 48-port line cards.

The Cisco Catalyst 4500E achieved 100-percent line-rate throughput for this traffic, for all frame sizes, with no packet loss. With the same configuration, the Brocade FastIron SX 1600 switch dropped 50 percent of the packets.

With traffic overwhelming the Brocade switch causing significant data loss, packet latency tends to be very high.



Source: Miercom, December 2014

4.0 Max Forwarding Information Base Table (FIB) Capacity

Test Objective

To determine the actual FIB (forwarding information base) or 'routing table' capacity for each switch – for IPv6 forwarding – and compare those figures with the vendor's published specifications.

How We Did It

Each switch was configured with just two active ports. Then, "N" IPv6 routes were added to the routing table on each switch under test, up to the number cited in published specifications. Conversions were made, as appropriate, between the decimal values (i.e., 128,000) and the binary equivalent (i.e., 128K, which actually means 131,072 entries).

On the Brocade switch, the max number of IPv6 routes is set by default to 32K (32,768). So the default value first had to be increased, up to the maximum of 64K (65,536) per the vendor's datasheet, and then routes added. No such configuration to increase the maximum value was required on the Cisco switch.

Results and Analysis

The FIB table capacities specified in the datasheets of both the Cisco Catalyst 4500E and the Brocade FastIron SX 1600 were validated, as shown in the table below:

	IPv6 Data Sheet Numbers	
Cisco Catalyst 4500E	128K	**Verified**
Brocade FlatIron SX 1600	64K	**Verified**

The number of routes specified above was defined between the two active ports on each switch. We confirmed that the routes were created successfully by querying the switches' route summaries. As an example, the IPv6 route-table capacities were verified with the following summary command:

On the Brocade FastIron SX 1600:

```
Brocade# sh ipv6 route summ
IPv6 Routing Table - 65536 entries:
2 connected, 0 static, 0 RIP, 65534 OSPF, 0 BGP
```

On the Cisco Catalyst:

```
Cisco# sh ipv6 route summ
IPv6 routing table name is default(0) global scope - 131072 entries
Total     131072    14680064    17301504
```

Both switches support the maximum number of routes advertised – per their respective datasheets.

The Cisco Catalyst 4500E supports a more scalable IPv6 deployment with twice the number of IPv6 routes than does the Brocade FastIron SX 1600.

Bottom Line

In summary, Catalyst 4500E Series switch, the industry leading modular access platform, offers best-in-class investment protection with high availability, predictable high performance, increased control and flexibility. For all tests performed for various types of traffic, the performance of Cisco Catalyst 4500E switch surpassed that of Brocade SX 1600 switch.

Independent Evaluation

This report was sponsored by Cisco Systems, Inc. The data was obtained completely and independently as part of Miercom's competitive analyses.

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