# Comparative Analysis:

## Cisco Catalyst 4500E

## HP 5400R zl2

DR150313D

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Miercom
www.miercom.com

# Contents

# 1 - Executive Summary

Miercom was engaged to perform comparative testing of two high-capacity, modular enterprise access switches: the popular Cisco Catalyst 4500E, and a comparably configured, competitive switch, the HP 5400R zl2, from Hewlett-Packard Company.

Miercom conducted hands-on testing and assessed the performance of select features that are critical for the reliable operation of enterprise networks. The switches were tested side-by-side in a well-equipped West Coast test lab.

Key Findings:

| | |
|---|---|
| Cisco accommodates much larger data bursts with no loss | Testing found the Cisco Catalyst 4500E accommodates up to nine times larger data bursts, delivered to otherwise loaded output ports, without loss, than the HP 5400R zl2. |
| Significantly greater Access Control List (ACL) capacity | The Cisco switch supports much greater ACL capacity than the HP switch, as well as ACL sharing across ports for both IPv4 and IPv6 ACLs, improving security efficiency. |
| Software-upgrade Downtime | Testing found that during active software upgrades, downtime and lost data is 35 times greater with the HP 5400R zl2 than the Cisco 4500E. |
| Simplified Diagnostics via embedded Wireshark | With an integral Wireshark data-capture, decode and analysis tool, the Cisco Catalyst 4500E enables straightforward local data-flow diagnostics. |
| Significantly greater Routing Table Capacity | Testing found the Cisco Catalyst 4500E supports more than 25 times as many IPv4 and IPv6 routes than the HP 5400R zl2, supporting larger deployments and future-proofed growth. |
| Higher 10GE port density | The Cisco Catalyst 4500E offers much higher 10GE port density compared to the HP 5400R zl2. |
| Comparable 10GE-Line-Card Cross-Fabric Throughput | The maximum bidirectional throughput between eight 10GE ports on one line card and eight 10GE ports on another card were comparable, achieving about 96 Gbps of throughput. |

Miercom has independently verified key performance aspects and feature differences between the Cisco Catalyst 4500E and the HP 5400R zl2. With better handling of data bursts, superior security via ACL capacity, quicker software upgrade and greater IP-route capacity, we present the *Miercom Performance Verified* certification to the Cisco Catalyst 4500E as a result of this comparative switch testing.

Robert Smithers

CEO

Miercom

## 2 - About the Products Tested

The switches that were tested are both high-capacity modular enterprise network switches, which can serve in access, aggregation or core layers depending on modules and configuration.

### Cisco

The Cisco switch tested was the Cisco Catalyst 4510R+E, 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 8-E modules. The latest Supervisor Engine 8-E was employed in the testing. The Cisco switch in our testing ran software version IOS-XE 03.07.00E.

*Cisco Catalyst 4510R+E, shown here with two redundant Supervisor 8-E modules in the middle.*

The 24-inch-high (14 RU) Catalyst 4510E chassis has eight line card slots, and the vendor offers an extensive range of line cards, varying in speed, number and type of ports and media (copper/RJ-45, including with or without PoE, or fiber SFP and SFP+).

The Cisco Catalyst 4500E switch with Supervisor Engine 8-E supports configurations with up to 384 Gigabit Ethernet (1GE) access ports, or up to 104 x 10-Gigabit Ethernet (10GE) fiber ports (eight uplink ports plus 96 line card ports). In a single chassis with dual supervisors, 4 uplinks are active on each supervisor thereby providing uplink redundancy when these ports are deployed as 10GE uplinks in access deployment.

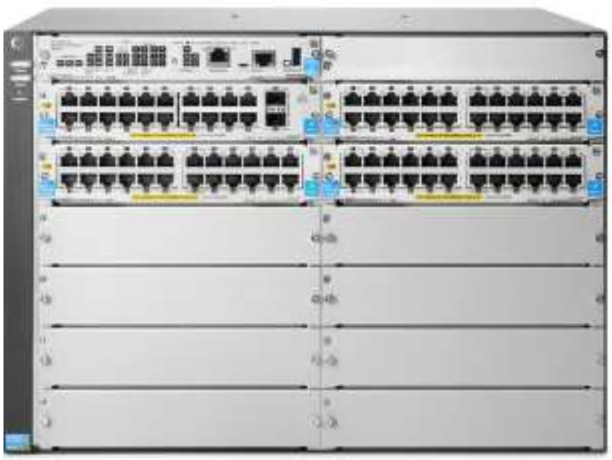
The Cisco Catalyst 4510R+E chassis tested (see below) was configured with the following modules:

| Slot | Number Ports | Description | Model/Part number |
|---|---|---|---|
| 1 | 12 | 10 Gigabit Ethernet SFP+ line card | WS-X4712-SFP+E |
| 5 | 8 | Supervisor 8-E, 10GE (SFP+), 1000BaseX (SFP) | WS-X45-SUP8-E |
| 6 | 8 | Redundant Supervisor 8-E, 10GE (SFP+), 1000BaseX (SFP) | WS-X45-SUP8-E |
| 9 | 12 | 10 Gigabit Ethernet SFP+ line card | WS-X4712-SFP+E |

## HP

The HP switch tested was the HP 5400R zl2, a 12-slot switching system – plus two dedicated slots at the top for one or two (redundant) management modules. Software version KB.15.16.0005 was run for all our tests.

The switching system can serve access, aggregation or core roles, depending on modules and configuration. Also, as with the Cisco 4500E, more than a dozen different line-card modules are offered, which vary in port speed and connection type (RJ-45 copper, including PoE, and fiber SFP and SFP+).



*The HP 5400R zl2 switch features two vertical side-by-side chassis rows, offering 12 slots for line cards, plus two dedicated slots on top for one or two management modules. The switch is shown here with four 24-port GE line-card modules.*

The 12-inch-high (7 RU) HP 5412R zl2 chassis can deliver up to 288 Gigabit Ethernet ports, or up to 96 x 10GE ports (RJ-45 copper or fiber SFP+).

In terms of form-factor for enterprise deployment, Cisco has a practical advantage with the Catalyst 4500E being only 12.5" (31.8 cm) deep for easy deployment in tight spaces. It also has easy access to power supplies through the front for easy serviceability. In contrast, the HP 5400R zl2 has 42% more depth at 17.75" (45.1 cm). On top of that, HP 5400R zl2 would require at least 12" to 18" (30 cm to 45 cm) in the rear to pull out power supplies for servicing.

The HP 5400R zl2 switch tested (see below) was configured with the following modules:

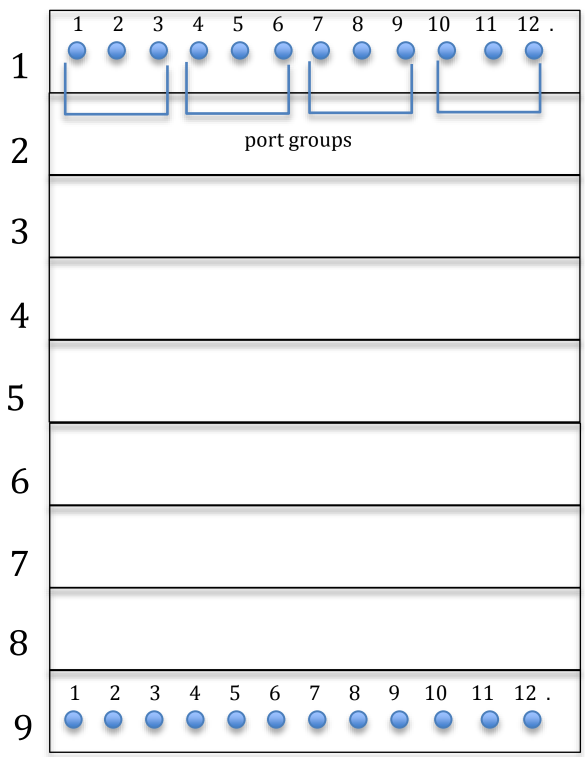
| Slot(s) | Number Ports | Description | Model/Part number |
|---|---|---|---|
| Top 2 | -- | 2 x (redundant) HP 5400R zl2 Management Modules | J9827A |
| A (top left) | 8 | HP 8-port 10GbE SFP+ v2 zl Module | J9538A |
| K (bottom left) | 24 | HP 24-port Gig-T PoE+ v2 zl Module | J9534A |
| L (bottom right) | 8 | HP 8-port 10GbE SFP+ v2 zl Module | J9538A |

## Comparing 10-Gigabit Ethernet (10GE) Line Cards

The 10GE line cards used for this testing were the latest, highest-port-density versions of 10GE line cards offered by these vendors for these switches at the time of testing.  The 10GE line cards of Cisco and HP are architected differently, however.  While it is possible in either case for any port on either vendors' 10GB line card to send and receive data at the full line rate of 10 Gbps, it is **not** possible – in either case – for **all** ports on the card to send and receive at the full line rate of 10 Gbps **at the same time**.

It is useful in understanding the 10GE-port throughput test results that follow to understand how these line cards are architected differently.  In Cisco's case, the 12 ports on the 10GE SFP+ line card (part WS-X4712-SFP+E) are aggregated into four groups of three ports each, as shown in the diagram below.

Cisco 4500E w/ 12-port 10GE Line Cards




Group 1 contains ports 1, 2 and 3

Group 2 contains ports 4, 5 and 6

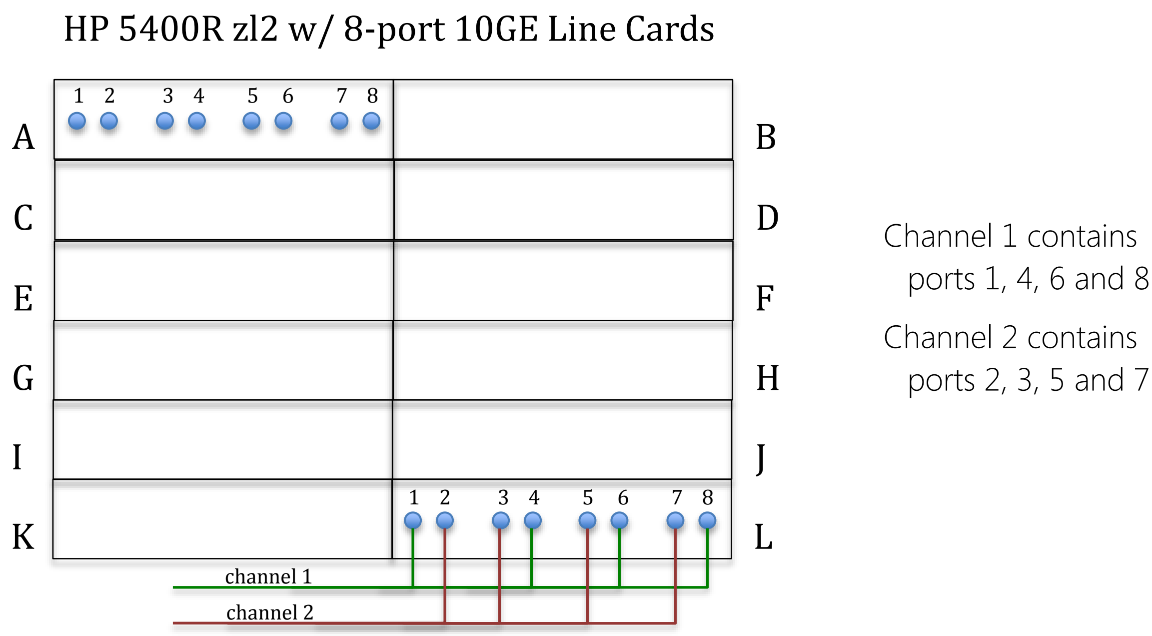
Group 3 contains ports 7, 8 and 9

Group 4 contains ports 10, 11 and 12

The operational and performance characteristics of the ports are as follows:

- Each port is rated at 10GE and can, by itself, achieve full rate throughput of 10 Gbps (20 Gbps bi-directionally) max
- Each group of 3 ports on the line card collectively shares 12 Gbps throughput (24 Gbps bi-directionally)
- The line card, with all 4 port groups (all 12 ports) collectively supports a total of 48 Gbps throughput (96 Gbps bi-directionally).

The 10GE ports on the HP eight-port line card (part **J9538A)** have similar architectural limitations. As shown in the diagram below, the eight ports are aggregated onto two "channels."




The operational and performance characteristics of the ports are as follows:

- Each port is rated at 10GE and can, by itself, achieve full rate throughput of 10 Gbps (20 Gbps bi-directionally) max
- 4 ports of the 8 port 10G line card use channel 1 and the other 4 ports use channel 2 to connect to the switch fabric.
- Each channel on the line card collectively supports 23.4 Gbps throughput (46.8 Gbps bidirectionally)
- The line card with both channels (all eight ports) collectively supports a total of 46.8 Gbps throughput (93.66 Gbps bidirectionally)

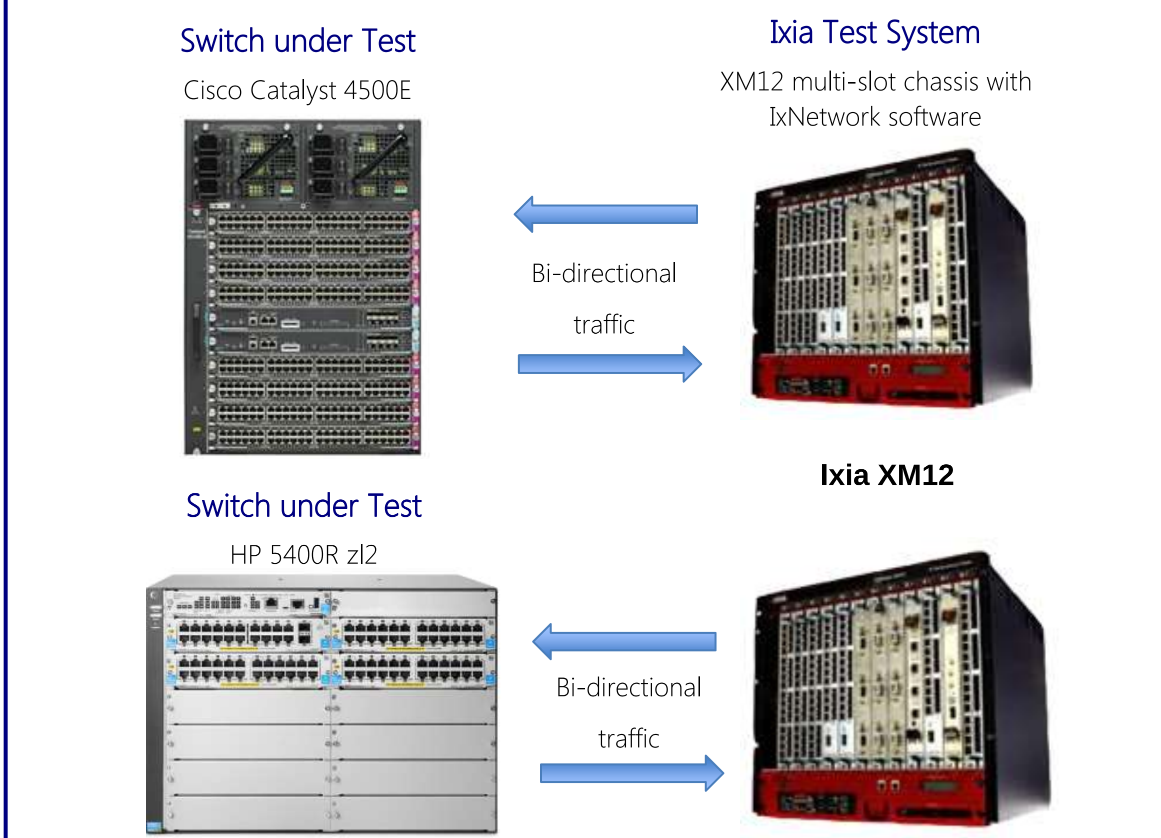
Users will want to keep these architectural differences in mind for deployment – such as using just one or two ports per group, or two or three ports per channel, for heavily loaded backbone links. Also, users should note these limitations when viewing the throughput results of this testing. In the main test case, we sought to determine the maximum throughput that could be achieved from the 10GE ports on one line card, across the backplane, to the 10GE ports on another line card.

Since the HP switch supports eight 10GE ports per line card, the throughput test was devised to deliver bidirectional data between the eight ports on two different line cards, one at the top and the other near the bottom. For purposes of a fair comparison, the Cisco switch was likewise tested, in the same manner, between eight ports on two of its 12-port line cards.

# 3 - Test Bed Setup

All tests of the Cisco and HP 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 IxNetwork application as the primary traffic generator that drove network traffic through the switches. IxNetwork offers a vast library of test methodologies. Ixia ([www.ixiacom.com](http://www.ixiacom.com)) is an industry leader in the 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 Layer 2-to-Layer 7-based networking products.




Source: Miercom, March 2015

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](mailto: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.

# 4 - Throughput with No Packet Loss

*"Cisco Catalyst 4500E offers significantly higher port density with a similar throughput performance to the HP 5400R zl2 with v2 modules."*

## Objective

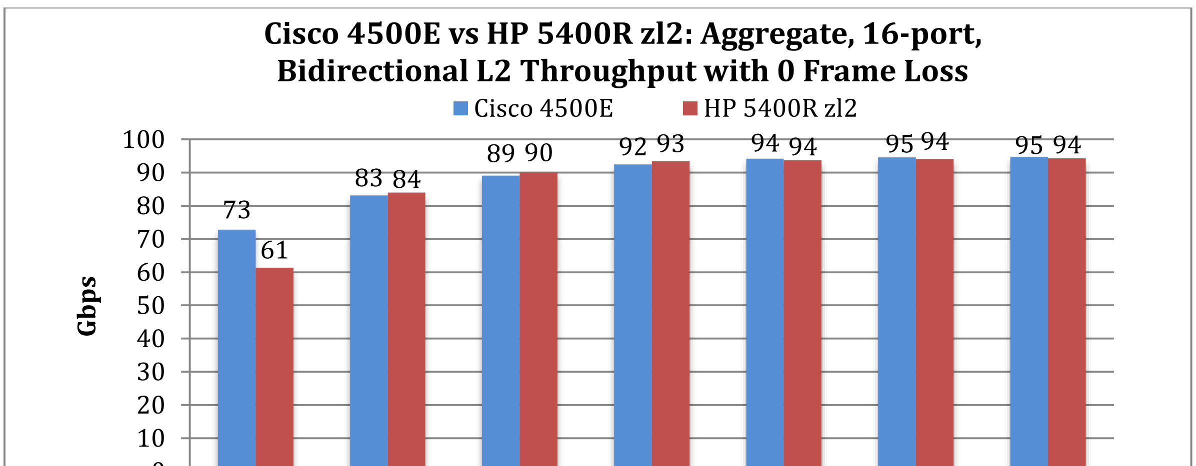
To determine the maximum throughput that can be obtained, with no loss, between 16 ports, on two 10GE line cards, across the switch fabric.

## How We Did It

In this test we sought to determine the maximum throughput that could be achieved from the 10GE ports on one line card, across the switching fabric, to the 10GE ports on another line card. The Ixia test system was connected to 16 ports on each switch, and delivered bidirectional traffic at various packet sizes. The traffic switching performance was measured using the RFC 2544 test available in IXIA that searches for the maximum throughput with no packet loss.

Since the HP switch supports just eight 10GE ports per line card, the throughput test was set-up to deliver bidirectional data between the 16 ports on two different line cards, with eight ports on a line card at the top and the other line card near the bottom of the chassis.

The Cisco switch was likewise tested in the same manner: Bidirectional traffic was generated between 16 ports on two of its 10GE line cards, in the same switching system, across the switching fabric, and adjusted until the max throughput rate with no loss was determined.




| Frame Size | 64 | 128 | 256 | 512 | 1024 | 1280 | 1518 |
|---|---|---|---|---|---|---|---|
| Cisco 4500E | 73 | 83 | 89 | 92 | 94 | 95 | 95 |
| HP 5400R zl2 | 61 | 84 | 90 | 93 | 94 | 94 | 94 |

Source: Miercom, March 2015

## Results Summary

Cisco and HP exhibited comparable performance. As the graph shows, total bidirectional throughput between 16 ports was between about 83 and 95 Gbps, depending on packet size.

This does not represent wire speed on all ports, due to the architectural constraints discussed earlier. Generally speaking, the test results showed that the realistic aggregate bidirectional throughput between two 10GE line cards – eight ports on each card – equates to roughly 60 percent of the combined, all ports' line rate. However, all things being equal, the throughputs between the Cisco and HP switches are comparable in this respect.

Using the previous architectural constraints and the performance results from these tests and the port density numbers based on the data sheets, several conclusions can be extrapolated:

- With 12 line-card slots (using v2 modules), the HP switch supports the equivalent of 48 x 10GE ports at line rate (4 GE ports at wire rate per 8-port 10GE line card, times 12 line cards).

- The Cisco Catalyst 4500E also uniquely supports the merger with another 4500E switch into a single Virtual Switching System, or VSS. The two switches are managed and behave as one. Up to eight 10GE links connect the two switches for traffic routing and switching. In a fully expanded VSS mode, then, the Catalyst 4500E supports 80 x 10GE ports at line rate (64 line-card ports plus sixteen 10GE Sup8-E uplink ports), less the number of 10GE ports used to link the two switching systems.

- In terms of total number of 10G ports, Cisco can support up to 208 10G ports in a single VSS system (192 line card ports + 16 Sup8-E uplink ports) while HP can do only 96 10G ports (12 line-card slots with 8 10G ports in each line card).

# 5 - Buffer-Depth Capacity Test

*"Cisco Catalyst 4500E offers up to nine times the burst capacity of the HP 5400R zl2 with v2 modules."*

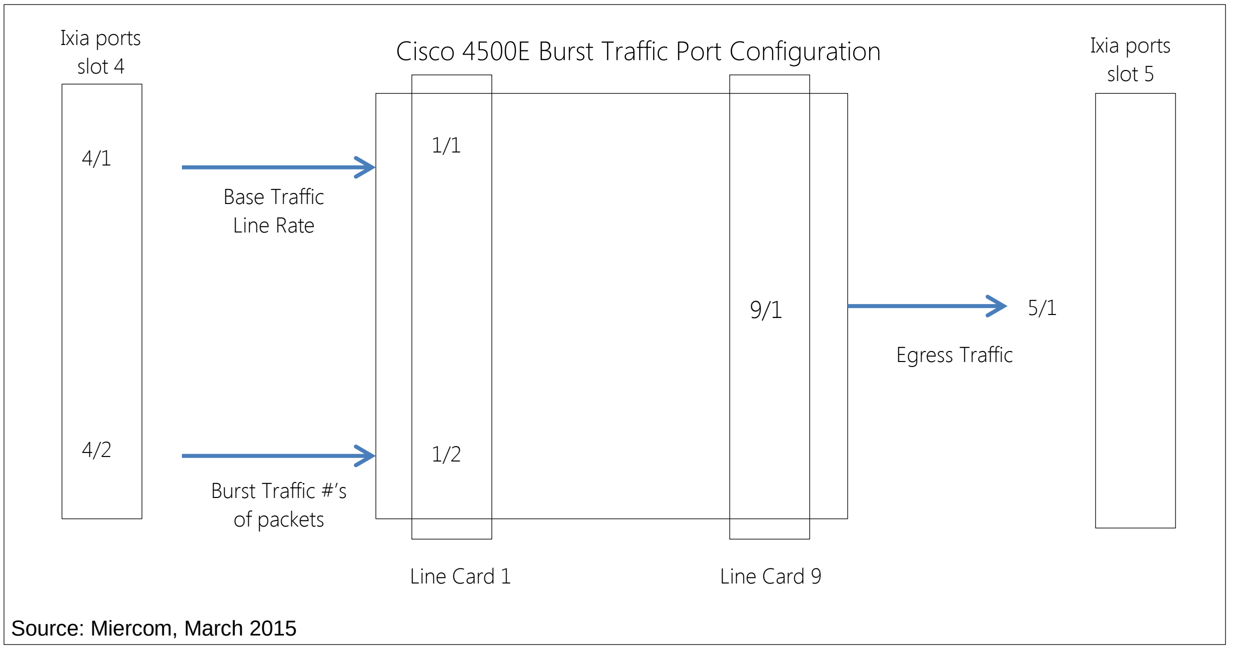
## Objective

When an outbound switch port is overloaded – that is, there is more data to be sent out than the port has bandwidth to send – the result is 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 HP switches accommodate data bursts.

## How We Did It

The test plan was to determine the "maximum burst size" that the switch could accommodate on an output port. The switch under test was configured with three active ports. The set-up for the Cisco switch test is shown in the diagram below.

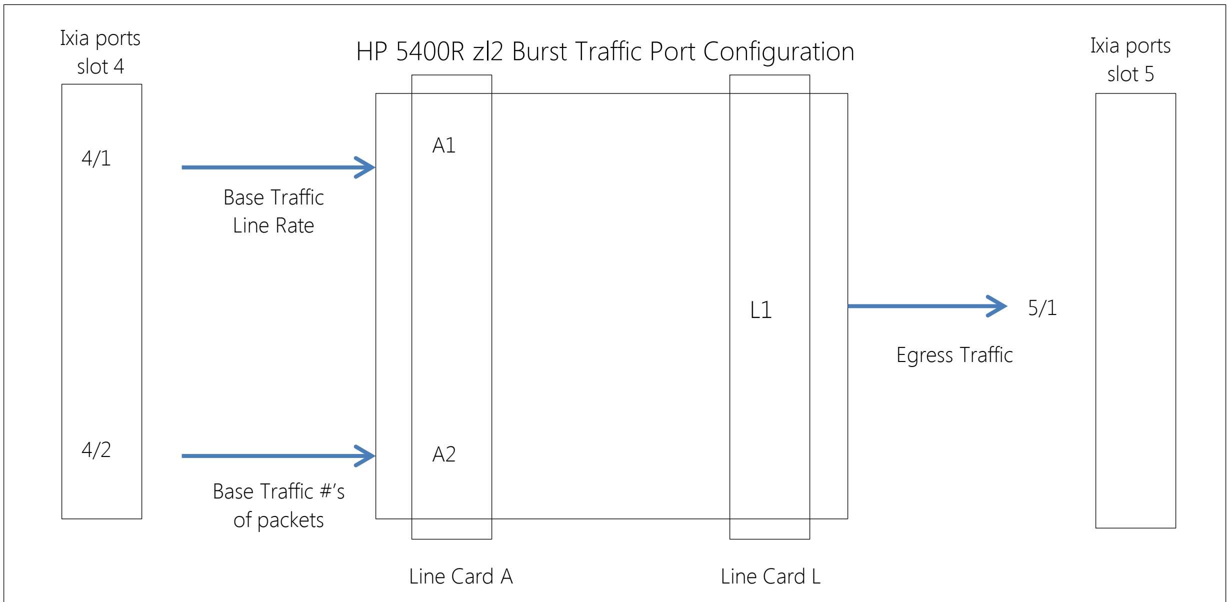


Source: Miercom, March 2015

The Ixia test system delivered a 10-Gbps, Layer-2 traffic flow in one direction to Port 1 on the 10GE line card in slot 1 of the Cisco 4500E switch. This line-rate "Base Traffic Flow" was forwarded to output on Port 1 on the 10GE line card in slot 9, and delivered back out to the Ixia traffic generator. This traffic flow, which changed for each test packet size, would fully load the outbound channel of Port 9/1. The Ixia would confirm that there was no packet loss.

Then, in addition to this stream, a single burst of a specified number of packets (at the current test packet size), is sent in on a different port (Port 1/2). The line-rate, steadystate stream and the burst are forwarded to the same output port. All the output from this port is sent back out to the Ixia test system, which meticulously compares the sent traffic with the packets returned, looking for any dropped packets.

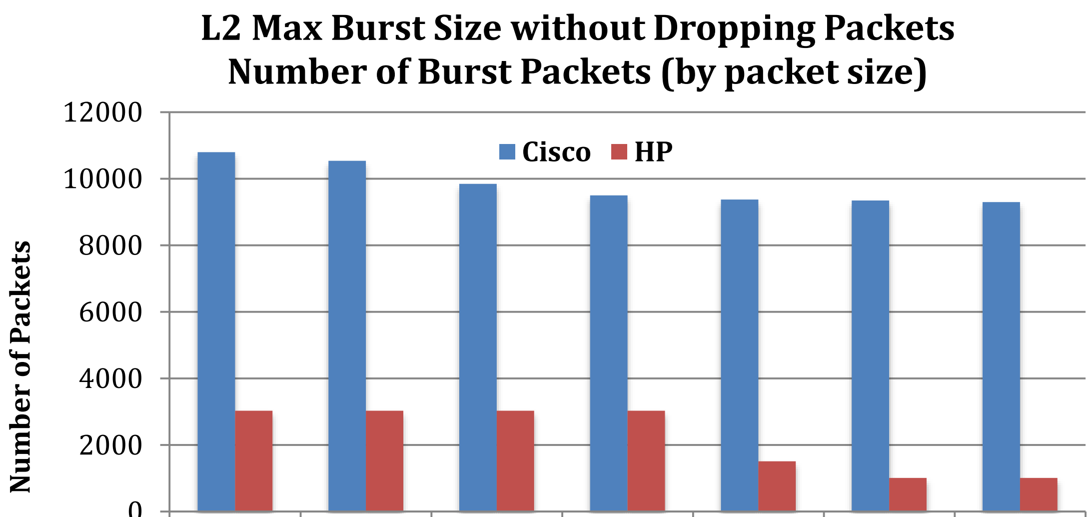
The size of the burst (the number of burst packets) sent is compared with the burst packets received and, if there is no loss, the burst size would be increased – until loss started to occur. Three test runs with 0 loss confirm that the "maximum burst size without packet loss" has been found (for that particular packet size). The number of packets for each such burst without loss, for each packet size, are then graphed and compared by packet size. The max burst size without loss equates directly to the output buffer depth of the line card.



Source: Miercom, March 2015

The same set of tests was then applied in the same manner to the HP 5400R zl2 switch (see above diagram). One port (Port 1 on the 10G line card in slot A) carried the Base Traffic Flow at line rate to the output port (Port 1 on the 10G line card in slot L), while and a second port on the line card A carries the burst flow of a specific number of packets.

## Results Summary




| Packet Size | 66 | 128 | 256 | 512 | 1024 | 1280 | 1518 |
|---|---|---|---|---|---|---|---|
| Cisco | 10800 | 10540 | 9850 | 9500 | 9370 | 9350 | 9300 |
| HP | 3031 | 3030 | 3031 | 3031 | 1515 | 1009 | 1009 |

Source: Miercom, March 2015

The graph highlights the differences in buffer management and buffer depth between the Cisco 4500E and the HP 5400R zl2 switches. The larger Cisco internal output buffers on the ports provide additional space to handle much larger traffic bursts without losing data. The differences are dramatic: At small packet sizes the Cisco 4500E accommodates over three times larger bursts with no packet loss than the HP 5400R zl2. At large packet sizes the Cisco 4500E accommodates over nine times larger bursts with no packet loss than the HP 5400R zl2.

# 6 - Security – ACL Support

*"The Cisco Catalyst 4500E has 128K ACL table entries compared to 8K entries per line card on the HP 5400R zl2 while using less than half of the number of table entries per ACL when compared with the 5400R zl2. This makes the Catalyst 4500E a highly scalable platform for secure deployments."*

A key security feature in today's networks is Access Control Lists, or ACLs. These are filters applied to switches, usually on a per-port basis, which allow or prohibit inbound and outbound packets. Filtering can be applied, for example, to the IP field, source or destination IP address, TCP/UDP port number, per-VLAN or per-port.

Besides security, ACLs help accomplish traffic-flow controls for Quality-of-Service (QoS) handling, as well as Role-Based Access Control, where users are restricted or authorized access based on their locations or roles.

## Objective

ACLs are composed of ACE's (Access Control Entries), which are programmed as TCAM (Temporary Content-Addressable Memory) entries in the switch hardware for fast access while routing packets.

For example the following ACL "acl101" contains 5 ACE entries:

```
Switch#sh access-list acl101
Extended IP access list acl101
    10 permit tcp any any eq 1
    20 permit tcp any any eq 2
    30 permit tcp any any eq 3
    40 permit tcp any any eq 4
    50 permit tcp any any eq 5
```

The ACLs are limited by the number of ACE entries that can be created through the Command Line Interface (CLI), the number of TCAM hardware entries on each line card, and the total number of TCAM entries allowed in the system.

NOTE: When an ACE is programmed into a TCAM, it may take up 1 or more TCAM entries depending on the implementation. For example, when you bind the above ACL with 5 ACE entries to a port on Cisco switch, it results in programming of 7 TCAM entries. On the other hand, when you bind the same ACL with 5 ACE entries to a port on HP switch, it results in programming of 22 TCAM entries. This shows that ACL programming on Cisco switch is much more efficient and scalable as compared to that on HP switch.

In this testing we examine several aspects of the Cisco 4500E and HP 5400R zl2 switches:

- The maximum number of ACL HW entries that each switching system supports
- The ability to share common ACLs, for better efficiency and capacity utilization.

### How We Did It – Cisco 4500E

To verify the maximum number of Cisco ACEs, we created multiple IPv4 Inbound ACLs, each containing 10,000 ACEs (matching on TCP port) that result in programming of 10,177 TCAM entries. We applied one such ACL to each 10G port on a single line card. We adjusted the last ACL's entries to just max out the ACL TCAM entries for Inbound IPv4 ACEs. In total we were able to apply 58358 ACE entries, with each ACE entry defined to match on TCP port.

For this test we counted only ACEs that are stored in the TCAM memory. On Catalyst switch, ACEs can also be stored in software buffers, but access to them is much slower, so we ignored those for this test.

### Results Summary

We maxed out the Cisco switch with 59,392 TCAM entries allocated on the IPv4 Inbound Security Group.

We obtained the following Cisco Content Addressable Memory (CAM) utilization statistics:

#sh platform hardware acl stat utilization br

sh platform hardware acl stat utilization br
CAM Utilization Statistics

| | | Used | Free | Total |
|---|---|---|---|---|
| **Input Security** | (160) | 59392 (100%) | 0 (0 %) | 59392 |
| **Input Security** | (320) | 34 (1 %) | 2014 (99 %) | 2048 |
| **Input Forwarding** | (160) | 7 (0 %) | 2041 (100%) | 2048 |
| **Input Forwarding** | (320) | 24 (1 %) | 2024 (99 %) | 2048 |
| | | | | |
| **Output RoleBased** | (160) | 0 (0 %) | 2048 (100%) | 2048 |
| **Output Security** | (160) | 6 (0 %) | 2042 (100%) | 2048 |
| **Output Security** | (320) | 12 (0 %) | 2036 (100%) | 2048 |
| **Output Qos** | (160) | 10 (0 %) | 2038 (100%) | 2048 |
| **Output Qos** | (320) | 2 (0 %) | 2046 (100%) | 2048 |
| **Output Unallocated** | (160) | 0 (0 %) | 55296 (100%) | 55296 |

The output above shows that all the 59,392 IPv4 ACL TCAM entries for inbound security have been programmed, with an additional 6,079 TCAM entries still available for inbound IPv6 security and IPv4 forwarding for a total of 65536 (64K) ACL entries.

In addition there remains available space for another 65536 (64K) ACL entries for outbound filters.

The net result: There is room for 128K Inbound and Outbound ACL HW entries in the Cisco 4500E across all line cards in the Chassis.

### How we did it - HP 5400R zl2 switch.

We applied similar IPv4 ACE entries (matching on TCP port) to a 10G port in slot A of the HP 5400R zl2 switch. On HP switch, each ACE entry matching on TCP port results in programming of 4 ACL TCAM entries.

The maximum ACL TCAM entries available on a per line card basis of HP switch is 8,176 entries.

We maxed out this ACL TCAM space with just 2,044 ACE entries (2043 entries matching on TCP port + 1 explicit deny all entry) as verified by the output of the command "sh access-list resources":

HP-5412Rzl2# sh access-list resources

| Slots | Rules Available | ACL | QoS | IDM | VT | Mirr | PBR | OF | Other |
|---|---|---|---|---|---|---|---|---|---|
| A | 0 | 8176 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| K | 8176 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| L | 8176 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

We tried applying more ACEs to a different port of the same line card, we got the error:

"Unable to apply Access Control List. Failed to add entry 10."

Thus maximum number of ACL TCAM entries is limited to 8,176, for a line card on HP switch, with a port limited to only the TCAM entries that are available on the corresponding line card.

For the 12 line card slot chassis, that would limit the ACLs across all the line cards to (8176 per card X 12 cards) = 98,112 HW ACL entries.

### ACL sharing

Another key difference between switches, our testing showed, is that Cisco allows sharing of ACLs across all ports on line cards in the 4500E switching system, without consuming additional ACE memory space.

To verify this we filled nine of the 12 ports on the line card in Slot 1 with ACLs and ACEs, as in the previous ACL capacity test. We verified that no new ACLs could be bound to any port in the system.

We then attempted to share "ACL110," an ACL we had previously created and bound to port 1/1, with the remaining ports on the line card in Slot 1, and to the ports on the line card in Slot 9.

The Cisco 4500E accepted the shared ACL on the remaining ports on the line card in Slot 1, and also on all the ports on the line card in Slot 9. The ACL "ACL110" was successfully shared across all the remaining ports in the system when the system could no longer accept the binding of new ACLs to any ports.

The HP 5400R zl2 does not allow sharing of ACLs to conserve TCAM space even if the same ACL is used in which case the duplication consumes additional resources.

*"In the case of Cisco Catalyst 4500E, applying the same ACL on multiple interfaces will consume only one set of ACL TCAM entries shared across those interfaces. The HP 5400R zl2, on the other hand, will program the ACL entries multiple times, once for each interface, thus consuming significantly more of its already limited ACL TCAM entries.*

*This ACL sharing capability allows the Catalyst 4500E to scale to much larger campus deployments."*

The ACL capacities and capabilities verified by this testing, then, are as follows:

| | **Cisco 4500E** | **HP 5400R zl2** |
|---|---|---|
| **Total ACL capacity** | 131,072 (128K)/system | 8,176/card<br>98,112/system |
| **Ability to share ACLs among ports and cards** | Yes | No |

# 7 - High Availability – In-Service Software Upgrade (ISSU)

*"The Catalyst 4500E provides service continuity during software upgrades with the In Service Software Upgrade capability which HP 5400R zl2 does not have."*

## Objective

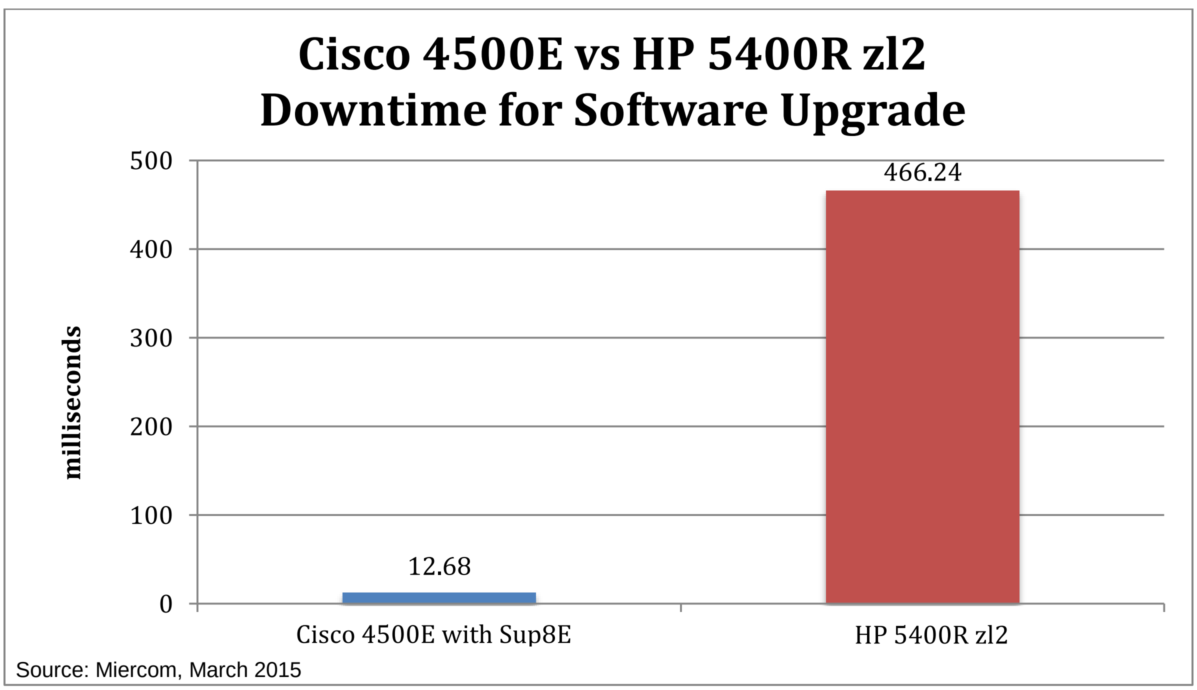
Both Cisco Catalyst 4500E and HP 5400R zl2 switches support redundant control modules – "supervisor" modules in Cisco's case, "management" modules in HP's case. Because of this it is possible to upgrade the switch's operating software while the switch continues full operation. So-called In-Service Software Upgrade – ISSU in Cisco parlance – is possible because the modules are redundant – one operates in an active role and the other as a back-up.

New software is loaded onto the back-up module and then, under user control, the module with the new software is switched to as the active and the active, with the old software version, is relegated to the standby role.

However, this switchover does involve a brief interruption to the system, which is unavoidable given the volumes of data that are in transit through the switch when the new module and new software take over. In this test we sought to quantify the extent and impact of this interruption.

## How We Did It

Both Cisco and HP switches uses two flash memory locations to store the two software versions.



## Results Summary

After the new software version is loaded into the boot flash on the standby, the system is rebooted from the standby, making it the active. Then the active module fails over to become the standby, and it reboots after loading the new software into its flash.

During this fail-over some packets are lost.

This test measures the duration of, and the amount of packets lost during, that failover period. The Ixia test system ran a single data stream of 256-byte IPv4 packets in one direction through 10GE ports at one-half line rate (5 Gbps).

Cisco. The Cisco 4500E's software version was upgraded from IOS XE 03.06.01.E to 03.07.00.E. Cisco employs one command "issu changeversion" that manages the whole software-version switchover.

HP. There are three steps involved in updating the HP 5400R zl2. Each action entails a separate command, but the actual failover is just one command. And like the Cisco system, this starts the interruption period where packet loss occurs.

| Cisco Catalyst 4500E with Sup8-E<br>(IOS XE 03.06.01.E -> IOS XE 03.07.00.E) | HP 5400R zl2<br>(KB.15.15.0008 -> KB.15.16.0005) |
|---|---|
| 1. Download new image | 1. Download new image |
| 2. Upgrade using single command:<br>ISSU change version bootflash:cat4500es8-universalk9.SPA.03.07.00.E.152-3.E.bin | 2. Make sure boot setting is configured to boot to correct flash software was copied to:<br>boot set-default flash primary |
| | 3. Boot standby module:<br>boot standby |
| | 4. Perform switchover:<br>redundancy switchover |

The Ixia system compared the sent and received packet stream and detailed every packet lost during the transition. With the number of lost packets known, and the packet size and packet-per-second rate known, calculating the downtime is a straightforward calculation.

The table below summarizes the impact and duration of the two switches' downtime.

Measured effect of In-Service Software Upgrade (ISSU)

| | **Cisco 4500E** | **HP 5400R zl2** |
|---|---|---|
| Test traffic rate, packets per second (pps) | 2,264,492 | 2,264,492 |
| Number of lost packets | 28,711 | 1,055,793 |
| **Downtime for switchover, milliseconds (ms)** | **12.68** | **466.24** |

The Cisco 4500E exhibits much less downtime to perform a software update than the HP 5400R zl2. With just 13 milliseconds downtime, data loss with the Cisco switch was 28,711 packets. With the HP switch, the downtime was more than 35 times longer, resulting in the loss of over a million packets.

# 8 - Max Forwarding Information Base Table (FIB) Capacity

*"The 4500E provides higher scalability with a FIB table size that is 25 times greater than the HP 5400R zl2, thereby ensuring capacity for current and future networks."*

To support the routing increases expected over the life of a major switching system, it is critical that the system be able to accept a large enough number of routes – IPv4, as well as IPv6 – to accommodate future growth and expansion.

## Objective

To determine whether the actual FIB (forwarding information base) capacities supported by the Cisco 4500E and HP 5400R zl2 switches, for both IPv4 and for IPv6 forwarding, meet their published capacity claims.

## How We Did It

To verify that each switching system could in fact handle their published number of supported routes, we created 10,000 IPv4 routes on the HP 5400R zl2 and 256,000 IPv4 routes on the Cisco 4500E. We then ran traffic that exercised each of the routes, to validate that each route had in fact been created and applied, and the switch could forward data appropriately without any data loss.

In a separate test afterwards we created 5,000 IPv6 routes on the HP 5400R zl2 and 128,000 IPv6 routes on the Cisco 4500E. As with the IPv4 route testing, we ran traffic that exercised each of the routes.

## Results Summary

Cisco. On the Cisco system, IPv4 route status was checked with the command:

#sh ip route summary, which showed the following:

| Route Source | Networks | Subnets | Replicates | Overhead | Memory (bytes) |
|---|---|---|---|---|---|
| application | 0 | 0 | 0 | 0 | 0 |
| connected | 0 | 8 | 0 | 576 | 1440 |
| static | 1 | 0 | 0 | 72 | 180 |
| ospf 1 | 0 | **256000** | 0 | 18432000 | 47104000 |

IPv6 route status was checked on the Cisco system with the command: #sh ipv6 route summary, which showed the following:

| Route Source | Networks | Overhead | Memory (bytes) |
|---|---|---|---|
| connected | 2 | 224 | 264 |
| local | 3 | 336 | 396 |
| application | 0 | 0 | 0 |
| ospf 1 | **128000** | 14336000 | 16896000 |

HP. IPv4 route status was checked on the HP 5400R zl2 with the command:

#sh ipv4 route summary, which showed the following:

| Protocol | Active Routes |
|---|---|
| OSPF Routes | **10000** |

And HP IPv6 route status was checked with the command: #sh ipv6 route summary:

| Protocol | Active Routes |
|---|---|
| Connected | 5 |
| OSPF3_Internal | **5000** |

## Results Summary

The FIB table capacities specified in the datasheets of both the Cisco Catalyst 4500E and the HP 5400R zl2 switches were validated.

## Supported FIB (Routing Table) Capacity

| | Cisco 4500E w/Sup8E | HP 5400R zl2 |
|---|---|---|
| IPv4 Routes | 256,000 | 10,000 |
| IPv6 Routes | 128,000 | 5,000 |

Testing verified that the Cisco 4500E supports more than 25 times the route capacity of the HP 5400R zl2.

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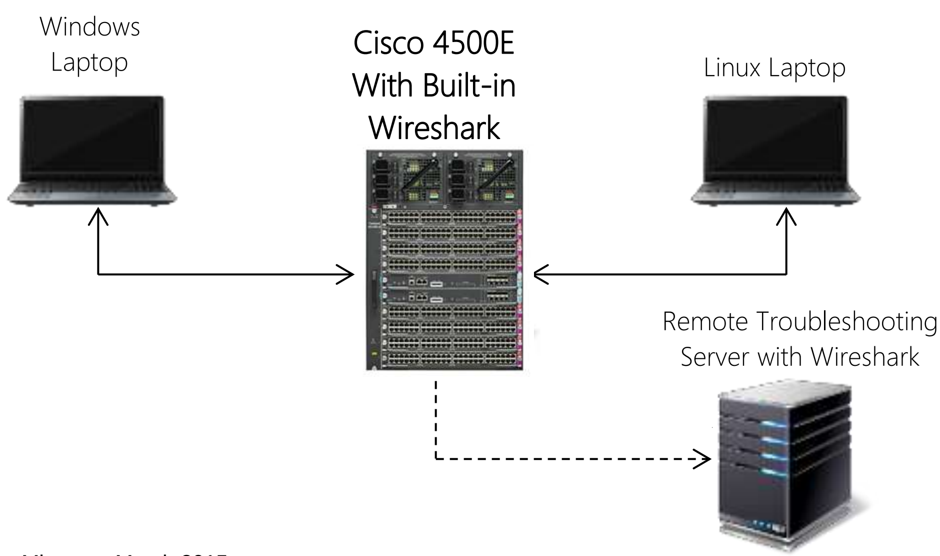
# 9 - Wireshark – Integral Switch-based Diagnostics

*"Cisco Catalyst 4500E simplifies and reduces the cost of network troubleshooting with the on-board Wireshark packet capture and analysis tool."*

Wireshark, a world-class data-capture, decode and diagnostic tool is built into the Cisco 4500E switch. This simplifies initial troubleshooting by allowing data monitoring to be set up on a per port basis, up to eight ports on a switch. Captured data is retained right in the Cisco 4500E's boot flash, from which the user can, via the built-in Wireshark CLI, do initial troubleshooting from the stored pcap (captured packet) file.

With the integral Wireshark, the requirement for port mirroring, which is the only way to accomplish this with the HP 5400R zl2, is eliminated. Port mirroring, also called SPAN or RSPAN, consumes additional ports, since another port has to be dedicated to receiving a copy of the data sent and received on the ports that are mirrored. It also requires that the port be already connected to the server that will receive the copy of the traffic. (Note: Catalyst 4500E also supports SPAN/RSPAN).

In our testing, we set up the Cisco 4500E to monitor traffic running between a Windows and a Linux laptop through the Cisco 4500E, and store a copy of the data flow in a boot-flash pcap file (mycap1.pcap). The diagram shows the configuration with the Cisco 4500E.

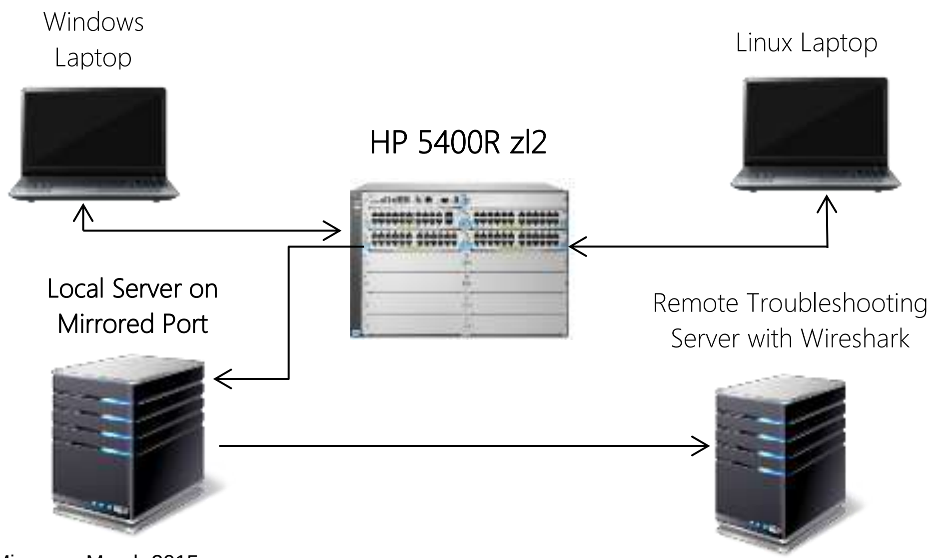



Source: Miercom, March 2015

Without an integral Wireshark, the mirrored-port approach typically requires another local server to collect and store the copied pcap data – what the Cisco 4500E with the integral Wireshark does locally in boot flash.

The file created by the Wireshark utility is a standard file in .pcap format and can be optionally exported and viewed using the standard Wireshark application on a PC.

The following configuration shows how the same functionality is achieved with the HP 5400R zl2.




Source: Miercom, March 2015

On HP 5400R zl2, you have to dedicate a port that will receive the copy of the traffic. Also you have to transfer the file to a remote machine running Wireshark application to be able to decode the captured packets.

From the Linux host, an "Hping2" SYN attack was launched against a server (Windows laptop), which traversed the Cisco Catalyst 4500E switch.

Wireshark was enabled on the Catalyst 4500E and filters were set up to capture ten seconds of traffic on port 2/11. The raw packets were captured and saved to local flash memory. The same packets could also have been exported to an external PC for further analysis. This process is shown below.

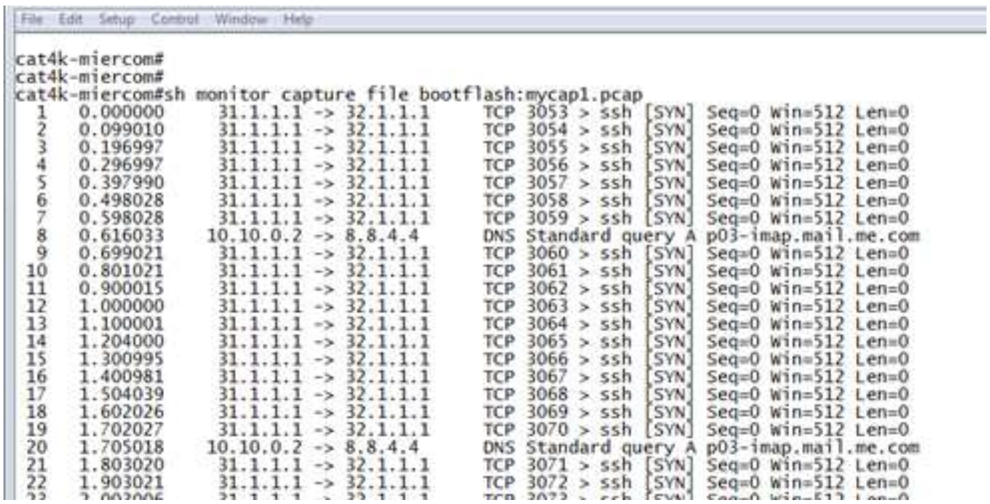
```
#sh monitor capture
Status information for Capture mycap1
  Interface: GigabitEthernet2/11, Direction: in
  Status: Active
  Filter Details:
    Capture all packets
 Limit Details:
  Number of Packets to capture: 0 (no limit)
  Packet Capture duration: 10
```

Packet Size to capture: 0 (no limit)

Packets per second: 0 (no limit)

Packet sampling rate: 0 (no sampling)

A condensed packet summary of the captured "ssh TCP SYN packets" and the "DNS queries" is shown in the Wireshark CLI sample screenshot below, via the command:




#sh monitor capture file bootflash:mycap1.pcap

We then used the CLI command "show monitor capture file <filename>" with the "detailed" option to decode and display all the fields of the packet on the console, enabling detailed analysis on the switch itself. Selected information from the decoded packets is shown here for simplification.

## Frame 7: TCP / SSH (TCP port 22) packet

Frame 7: 64 bytes on wire (512 bits), 64 bytes captured (512 bits)

Arrival Time: Feb 27, 2015 11:03:07.194981000 UTC

Epoch Time: 1425034987.194981000 seconds

*<snip>*

[Protocols in frame: eth:ip:tcp]

Ethernet II, Src: 74:46:a0:cd:9e:35 (74:46:a0:cd:9e:35), Dst: f8:66:f2:b4:a2:bf (f8:66:f2:b4:a2:bf)

*<snip>*

Internet Protocol, Src: 31.1.1.1 (31.1.1.1), Dst: 32.1.1.1 (32.1.1.1)

Version: 4

Header length: 20 bytes

Differentiated Services Field: 0x00 (DSCP 0x00: Default; ECN: 0x00)

*<snip>*

Header checksum: 0x1e40 [correct]
[Good: True]
[Bad: False]
Source: 31.1.1.1 (31.1.1.1)
Destination: 32.1.1.1 (32.1.1.1)
Transmission Control Protocol, Src Port: 3059 (3059), Dst Port: ssh (22), Seq: 0, Len: 0
Source port: 3059 (3059)
Destination port: ssh (22)
[Stream index: 6]
Sequence number: 0 (relative sequence number)
*<snip>*
.... ...0 = Fin: Not set
Checksum: 0x3a84 [validation disabled]
[Good Checksum: False]
[Bad Checksum: False]

## Frame 8: UDP Port 53 = DNS packet

Frame 8: 84 bytes on wire (672 bits), 84 bytes captured (672 bits)
Arrival Time: Feb 27, 2015 11:03:07.212986000 UTC
Epoch Time: 1425034987.212986000 seconds
*<snip>*
[Protocols in frame: eth:ip:udp:dns]
Ethernet II, Src: 74:46:a0:cd:9e:35 (74:46:a0:cd:9e:35), Dst: f8:66:f2:b4:a2:bf (f8:66:f2:b4:a2:bf)
Destination: f8:66:f2:b4:a2:bf (f8:66:f2:b4:a2:bf)
Address: f8:66:f2:b4:a2:bf (f8:66:f2:b4:a2:bf)
*<snip>*
Internet Protocol, Src: 10.10.0.2 (10.10.0.2), Dst: 8.8.4.4 (8.8.4.4)
Version: 4
Header length: 20 bytes
Differentiated Services Field: 0x00 (DSCP 0x00: Default; ECN: 0x00)
*<snip>*
Header checksum: 0xc0c2 [correct]
[Good: True]
[Bad: False]
Source: 10.10.0.2 (10.10.0.2)
Destination: 8.8.4.4 (8.8.4.4)
User Datagram Protocol, Src Port: 56717 (56717), Dst Port: domain (53)
Source port: 56717 (56717)

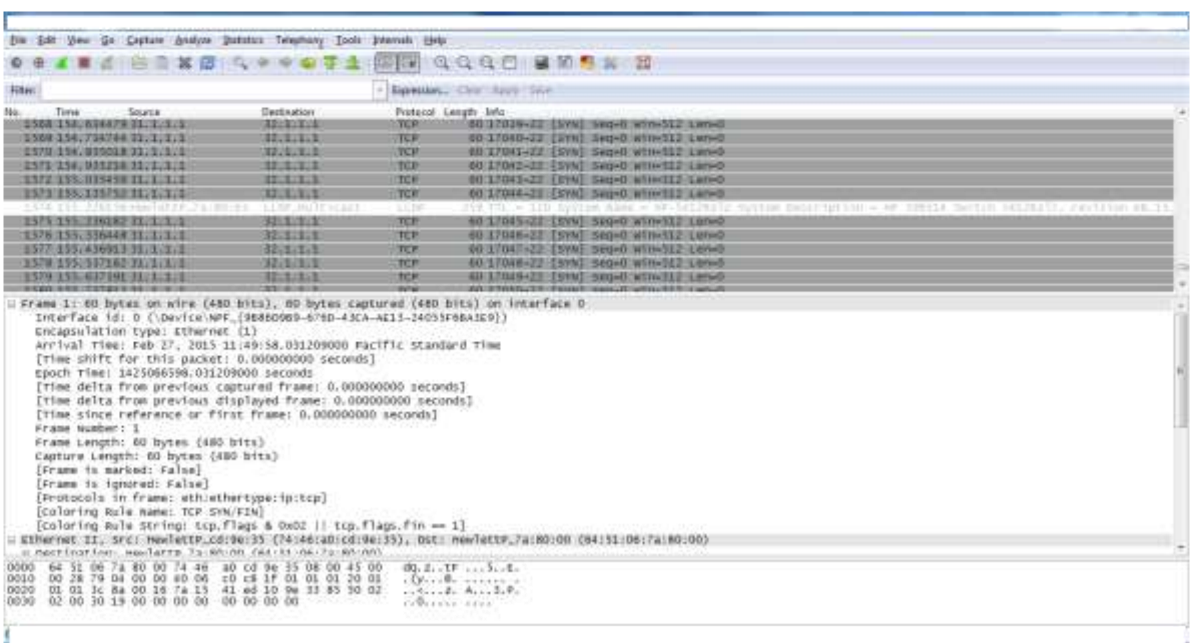
Destination port: domain (53)
Length: 46
Checksum: 0x92bf [validation disabled]
[Good Checksum: False]
[Bad Checksum: False]

Domain Name System (query)
Transaction ID: 0x25d5
Flags: 0x0100 (Standard query)
*<snip>*
Type: A (Host address)
Class: IN (0x0001)

The network diagnostician can remotely troubleshoot and verify by examining the packets' payload that a SYN DoS attack is underway. The tech can ascertain the source address, the target server, and the exact ports that the attack is targeting. Armed with this information remediation actions can be launched.

The test was repeated with HP 5400R zl2, however a similar packet analysis on HP switch required the desired packets to be sent to remote server running Wireshark application.

Here is a snapshot of the decoded packets from the Wireshark application running on a remote server:



## 10 - About Miercom

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## 11 - Use of This Report

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