#211127
September 2011
Commissioned by
Hewlett-Packard Company

HP 3800 Switch Series

Competitive Performance, Power Consumption and TCO Evaluation Versus Cisco Catalyst 3750-X and Juniper EX4200 Series

Executive Summary

Enterprise-class networks are facing increasing demands for higher port-density and throughput driven by rich media applications like voice and video over IP. Traditionally, network access layer switches delivered the port-density, fault-tolerance and scalability using either a chassis or a stack of fixed-port switches. Stackable switches, when properly architected, can offer network managers a solution that can be scaled as the needs of the network grow over time. In this report, the HP 3800 series switches were compared against Cisco's Catalyst 3750-X and Juniper's EX4200 series switches.

The performance of the HP FlexChassis-Mesh technology used by the HP 3800 Switch Series was compared against the Cisco Catalyst 3750-X with StackWise Plus technology, and Juniper's EX4200 switches using the Virtual Chassis stacking technology. Test results show the HP switches deliver significantly higher throughput at lower latency in both a standalone and in a four-switch stack configuration. According to HP, its new switches were designed with a large per-port buffer to deal with bursty traffic, allowing them to handle larger microbursts than the Juniper and Cisco switches.

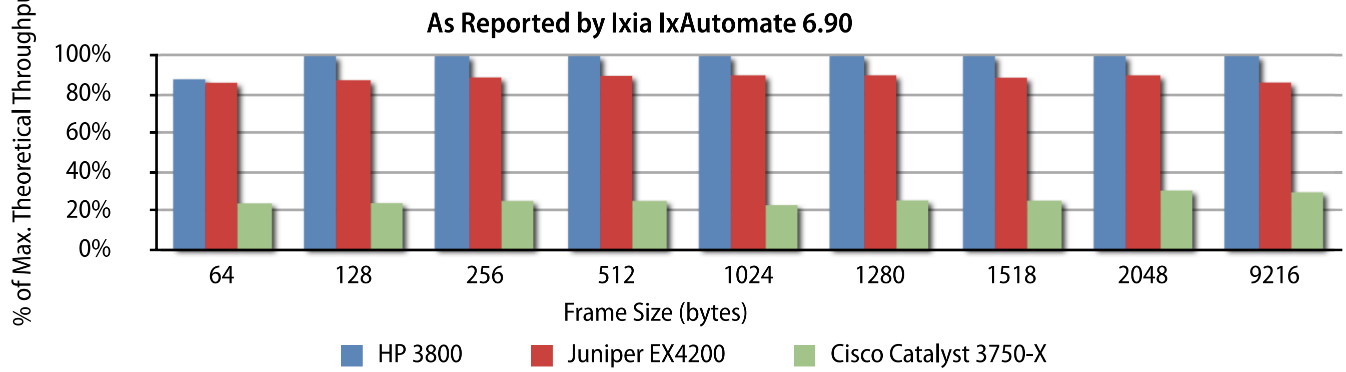
Furthermore, the HP switches showed demonstrably lower power consumption than the Juniper and Cisco switches. The HP switches implemented Energy Efficient Ethernet features, resulting in further savings in long-term power and cooling costs.

The Bottom Line

The HP 3800 series switches:

1. Delivered 1.2x and 4.4x the throughput delivered by Juniper and Cisco switches respectively
2. Outperformed standalone Juniper and Cisco switches by up to 20 Gbps and 27.5 Gbps respectively
3. Delivered up to 48% and 76% lower latency respectively than the Juniper and Cisco switches in a four switch stack
4. Buffered up to 3.6x and 25x as many frames in a microburst as the Juniper and Cisco switches, respectively.
5. Consumed up to 45% and 14% less power respectively than standalone Juniper and Cisco switches; and in four-switch stack configurations, the savings are 38% and 16% respectively
6. Demonstrated 44% and 35% savings in TCO over 3-years than 4-switch stacks of Cisco and Juniper switches respectively in a 5,000-port deployment

4-Switch Stack Performance: RFC 2889 Layer 2 Full Mesh Throughput
144 GbE Ports and 8 10GbE Ports in Dual Full Mesh*
As Reported by Ixia IxAutomate 6.90



Source: Tolly, July 2011 * Dual full mesh consisted of the GbE ports in one full mesh and the 10GbE ports in a separate full-mesh.

Figure 1

Background

Virtualization, video and audio are driving demand for higher performance and lower latency in the network. Consequently, the network access layer needs solutions that can not only meet today's performance needs, but also keep pace with the projected increase in network-intensive applications in the near future.

As mission critical applications like telephony, video, access points, etc... share a common data network infrastructure, guaranteed availability of the network becomes a very critical element of every network. Not only in the core but also at the edge of the network - hence having a cost-effective high availability (HA) solution is critical for future networks.

Network managers are simultaneously being asked to reduce the total cost of ownership, while retaining the aforementioned capabilities and performance. The consideration of networking gear acquisition costs and power consumption aspects are integral in selecting vendors and their equipment.

Performance Test Results

Performance tests focused on evaluating the aggregate throughput and latency exhibited by the products under test as per the RFC 2889 methodology. Each product under test was configured with 144 GbE ports in full-mesh and two 10GbE ports in a port-pair. This option was chosen to evaluate the performance when any port could send and receive traffic from any other port in the chassis or a switch-stack, thus representing a highly unrestricted distribution of traffic.

Layer 2 Throughput

The throughput tests show that the HP 3800 switch consistently delivered better throughput than the Cisco 3750-X and Juniper EX4200 switches: both in a standalone configuration, as well as in a four-switch stack.

In a single switch configuration, the HP 3800 switch delivered an aggregate throughput of 88 Gbps, equivalent to 100% of theoretical maximum throughput across its 48 GbE ports and four 10 GbE ports. The Cisco and Juniper switches were equipped similarly, except for two fewer 10GbE ports per switch. This meant that even though the Cisco and Juniper switches achieved 100% throughput across almost all frame sizes, the HP 3800 switch delivered 20 Gbps more throughput than Cisco and Juniper. The Cisco switch was unable to achieve line rate, coming in at ~13% below line rate in the jumbo frame size.

See Figures 1 and 2.

Hewlett- Packard Company

3800 Switch Series

Performance, Power Consumption and TCO Evaluation

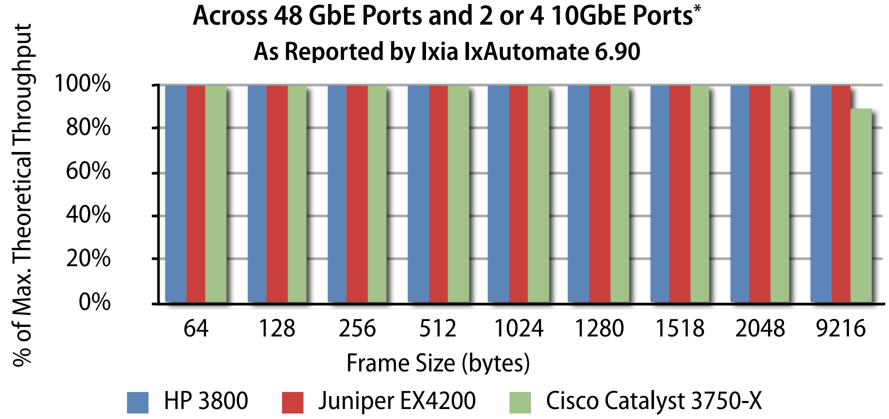
Tolly. Certified

Tested July 2011

Single Switch Performance: RFC 2889 Layer 2 Full Mesh Throughput

Across 48 GbE Ports and 2 or 4 10GbE Ports*

As Reported by Ixia IxAutomate 6.90



Frame Size (bytes)	Aggregate Throughput (Gbps)		
	HP 3800	Juniper EX4200	Cisco Catalyst 3750-X
64	88.00	68.00	68.00
128	88.00	68.00	68.00
256	88.00	68.00	68.00
512	88.00	68.00	68.00
1024	88.00	68.00	68.00
1280	88.00	68.00	68.00
1518	88.00	68.00	68.00
2048	88.00	68.00	68.00
9216	88.00	68.00	60.48

* The switches were tested in their configurations with maximum GbE and 10GbE ports supported per switch. The HP 3800 was equipped with 48 GbE and four 10GbE ports, while the Cisco Catalyst 3750-X and Juniper EX4200 were equipped with 48 GbE ports and two 10GbE ports.

Source: Tolly, July 2011 Figure 2

HP's Architectural Advantages†

Stacking Throughput:

The HP FlexChassis-Mesh technology supports 336 Gbps of bidirectional stacking throughput while Cisco's StackWise Plus stacking technology supports 64 Gbps and Juniper's Virtual Chassis technology supported 128 Gbps of stacking throughput.

Theoretically, this means the HP 3800 switches have 5.5x and 2.6x the stacking throughput of Cisco Catalyst 3750-X switches and Juniper EX4200 switches, respectively.

Stack Height:

The HP 3800 switches support stacking of up to 10 switches using the FlexChassis-Mesh technology, while the Cisco StackWise Plus technology allows for 9 switches and the Juniper Virtual Chassis technology allows for up to 10 switches in a single stack.

10GbE Port Density:

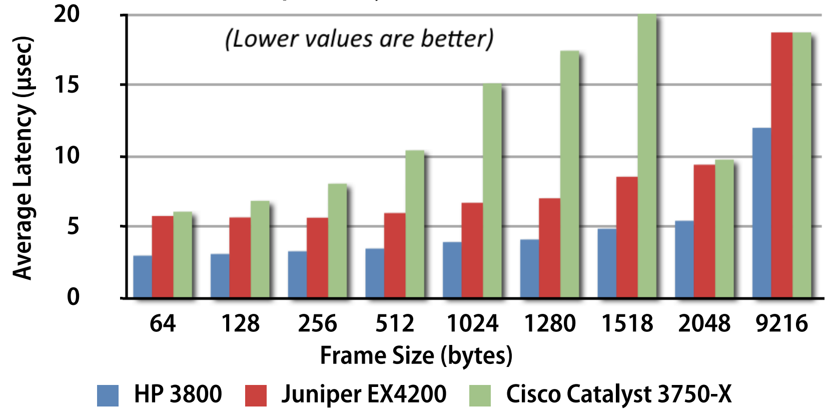
This allows the HP 3800 to support up to 40 10GbE ports in a stack (four 10GbE ports per switch) while the Cisco Catalyst 3750-X supports up to 18 10GbE ports (two 10GbE ports per switch), and the Juniper EX4200 supports up to 20 10GbE ports (two 10GbE ports per switch).

This means that the HP 3800 switch supports 2.2x the number of 10GbE ports in a stack compared to the Cisco Catalyst 3750-X, and 2x the number of 10GbE ports in a stack compared to the Juniper EX4200.

Disclaimer:

† Claims not validated by Tolly, but taken directly from the corresponding vendor's data sheet for the switch(es) under consideration.

RFC 2889 Layer 2 Store-and-Forward Latency
@10% Load Across 144 GbE Ports and 8 10GbE Ports in Dual Full Mesh*
As Reported by Ixia IxAutomate 6.90



Frame Size (bytes)	Average Store-and-Forward Latency (µsec)		
	HP 3800	Juniper EX4200	Cisco Catalyst 3750-X
64	3.0	5.8	6.1
128	3.1	5.7	6.9
256	3.3	5.7	8.1
512	3.5	6.0	10.5
1024	4.0	6.8	15.2
1280	4.2	7.1	17.5
1518	4.9	8.6	20.2
2048	5.5	9.4	9.8
9216	12.0	18.8	23.8

* Dual full mesh consisted of the GbE ports in one full mesh and the 10GbE ports in a separate full-mesh.

Source: Tolly, July 2011 Figure 3

Layer 2 Latency

The HP 3800 delivered consistently lower latency compared to the Juniper EX4200 and the Cisco 3750-X switches. The HP 3800 exhibited between 3.0 and 12.0 microseconds of latency for the 64- to 9216-byte frame sizes. In comparison, the Cisco 3750-X exhibited latency between 6.1 and 23.8 microseconds. This means that the HP switch delivered up to 76% and 48% less latency than Cisco and Juniper, respectively. See Figure 3.

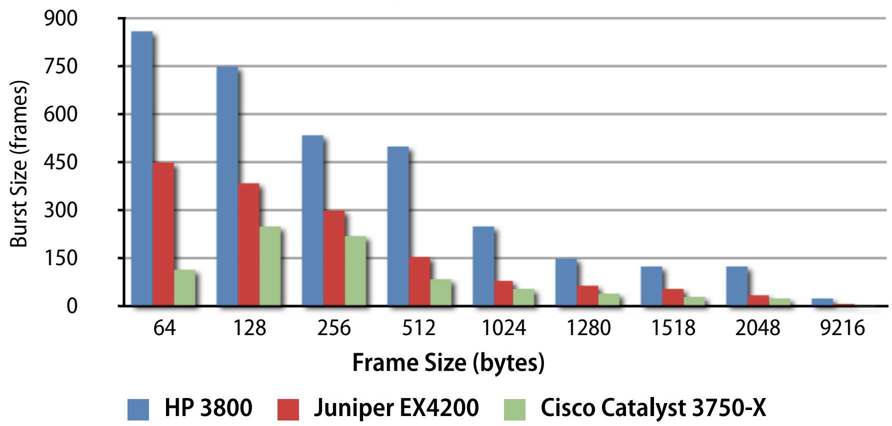
Microburst Tolerance

Microbursts are defined as sub-second periods of time when major bursts of network usage occurs causing the utilization of network interfaces to become temporarily oversubscribed. This can possibly result in packet loss depending on the network device's capacity to buffer the excess packets. The HP 3800 demonstrated the capability to buffer considerably larger microbursts - between .8 times to as much as 2.6 times more frames - compared to Juniper, and between 2 times and 24 times more frames compared to Cisco. See Figure 4.

The switches were configured with four queues, to match the highest number of queues supported by Cisco and Juniper. The HP switch supported 2, 4, or 8 queues, and HP engineers contend that with two queues, the HP switch could buffer larger microbursts from bursty applications and datacenter environments.

Microburst Tolerance With Simultaneous Bursts Across 48GbE Ports

As Reported by Ixia IxAutomate 6.90



Frame Size (bytes)	HP 3800	Juniper EX4200-48P	Cisco 3750-X-48P-S
64	860	450	115
128	750	385	250
256	535	300	110
512	500	155	85
1024	250	80	55
1280	150	65	40
1518	125	55	30
2048	125	35	25
9216	25	8	1

Source: Tolly, July 2011 Figure 4

Power Consumption

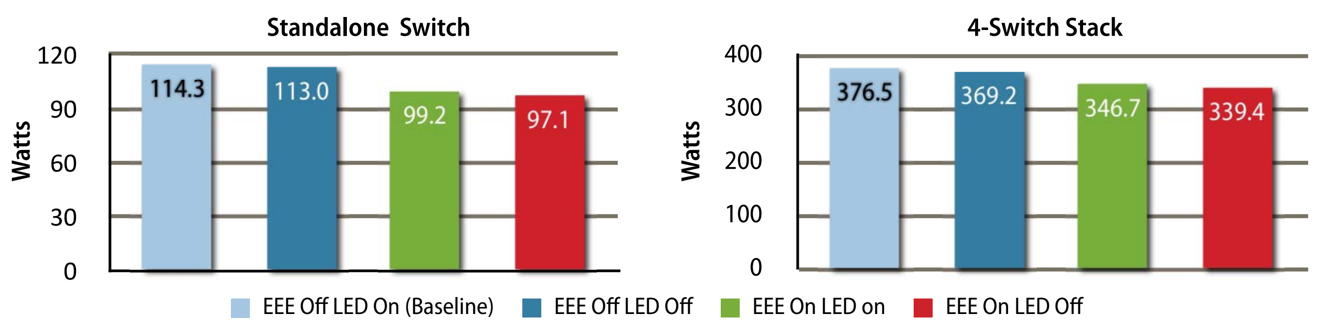
The HP 3800 series switches implemented power-saving features like Energy Efficient Ethernet (EEE), and the ability to turn off front-panel LEDs, resulting in further power savings over the product's deployment lifecycle. As shown in Figure 5, enabling EEE features and turning off the front-panel LEDs yielded power savings of almost 17 W per switch, and almost 37 W in a 4-switch stack, while the switches are in idle condition.

To evaluate the power consumption of the various switches under test, engineers measured power consumption at various traffic loads and then calculated weighted averaged power consumption as per the ATIS (Alliance for Telecommunications Industry Solutions) standards. See the Test Methodology section for details on the ATIS standards used. See Figure 6.

Total Cost of Ownership (TCO)

As can be seen in Figure 7, acquisition costs (hardware, software licensing, support contracts, etc.) as well as the power and

Power Consumption Savings at Idle
With Energy Efficient Ethernet (EEE) Features On HP 3800 Series Switches



Feature	Power Consumption of a Standalone Switch			Power Consumption of a 4-Switch Stack		
EEE Off, LED On (Baseline)	114.28 W	Savings over Baseline		376.5 W	Savings over Baseline	
EEE Off, LED Off	112.95 W	1%	1.33 W	369.2 W	2%	7.3 W
EEE On, LED on	99.21 W	13%	15.07 W	346.7 W	8%	29.8 W
EEE On, LED Off	97.12 W	15%	17.16 W	339.4 W	10%	37.1 W

Source: Tolly, July 2011 Figure 5

cooling costs of a standalone 48-port PoE/PoE+ switch and a stack of 4-switches were used to estimate the total cost of ownership (TCO) of a hypothetical 5,000-port deployment of the solutions tested over a 3-year period.

Engineers used single-unit street prices for the Cisco and Juniper switches based on CDW.com's prices in September 2011. Retail pricing for HP's equipment was estimated based on a 23% discount on top of HP's list price as the HP switches were not yet available at retail at the time of publication.

A detailed breakdown of the pricing used in the TCO model can be found in the companion document for this report, Tolly document 211127-Appendix.

The TCO estimates show that the HP 3800 series switches delivered significant TCO savings over comparable Cisco and Juniper switches.

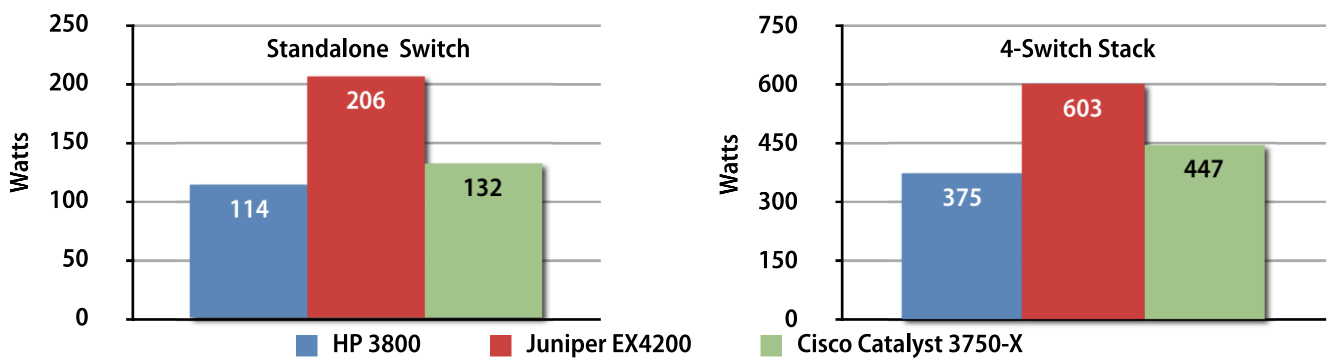
In a standalone 48-port PoE/PoE+ switch configuration, the HP 3800 switch delivered a savings of 54% and 53% in TCO over the Cisco Catalyst 3750-X and Juniper EX4200 switches, respectively.

In a 4-switch stack configuration, the HP 3800 switch delivered a TCO savings of 44% and 35% over the Cisco Catalyst 3750-X and the Juniper EX4200 switches, respectively.

Test Bed Setup

The devices under test consisted of up to four HP, Juniper and Cisco switches, as shown in Figure 6. Each vendor solution was connected to an Ixia Optixia XM12 traffic generator for test traffic generation and validation purposes. A laptop running Microsoft Windows 7 was connected to the

ATIS-Weighted Power Consumption (W_{ATIS}) and Projected Power and Cooling Costs over 3-Years



Device Under Test	Port Configuration	ATIS Weighted Average Power (W_{ATIS})	Projected 3-year Power and Cooling Cost (US$)
HP 3800	Standalone Switch (48GbE Ports)	113.70	$415.69
	4-Switch Stack (72 GbE PoE+ and 72 GbE Ports, 2 10GbE Ports)	374.87	$1,370.54
Juniper EX4200	Standalone Switch (48GbE Ports)	205.61	$751.73
	4-Switch Stack (72 GbE PoE and 72 GbE Ports, 2 10GbE Ports)	602.58	$2,203.05
Cisco Catalyst 3750-X	Standalone Switch (48GbE Ports)	131.58	$481.05
	4-Switch Stack (72 GbE PoE and 72 GbE Ports, 2 10GbE Ports)	446.92	$1,633.96

Note:
For a detailed breakdown of the acquisition costs and power consumption test results used to derive the power and cooling costs, please refer to the companion document to this report titled "Tolly211127-Appendix-HP3800SeriesTCOVsCisco3750XandJuniperEX4200" available at www.tolly.com.

† ATIS-weighted Power (W_{ATIS}) = 0.1*(Power draw @ 0% load) + 0.8*(Power draw @ 10% load) + 0.1*(Power draw @ 100% load)

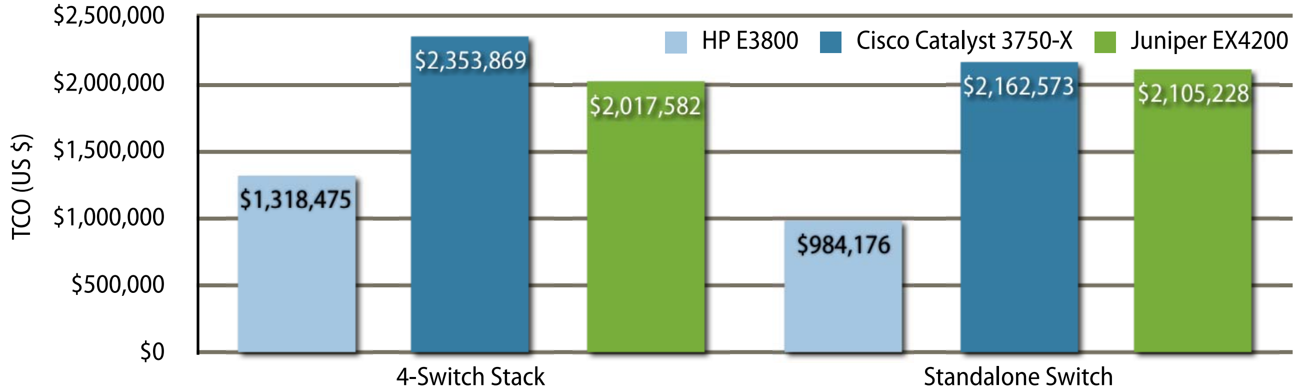
‡ FORMULA USED=(W_{ATIS}/1000)*(3*365*24)*(0.1077)*(1.33), where

- W_{ATIS}= ATIS weighted average power in Watts
- 3*365*24 = 3 years @ 365 days/yr @ 24 hrs/day
- 0.1077 = U.S. Average retail cost (in US$) of commercial grade power as of June 2011 as per Dept. of Energy Electric Power Monthly (Table 5.6A in the document available at http://www.eia.gov/electricity/monthly/pdf/chap5.pdf)
- 1.33 = Factor to account for power costs plus cooling costs @ 33% of power costs.

†† Test traffic consisted of an Internet Mix (iMIX) distribution of TCP packet sizes: 57% at 64-bytes, 7% at 570-bytes, 16% at 594-bytes and 20% at 1518-bytes

Source: Tolly, July 2011 Figure 6

Total Cost of Ownership Comparison of a 5,000-port Network Deployment of HP 3800 Switches Versus Cisco Catalyst 3750-X and Juniper EX4200



DUT	Port Configuration	Per Unit Acquisition Cost (US $)	Per Unit Power and Cooling Costs Over 3 yrs. (US $)	No. Of Units in a 5,000-port Deployment	Projected 3-year TCO (US $)
HP 3800	4-switch stack with 72 GbE POE+ and 72 GbE ports, and 12x 10GbE ports (J9574A, J9575A, J9576A, J9573A)	36,037.02	1,411.16	35	**1,310,686.30**
	Standalone switch with 48 GbE POE+ ports and 4x 10GbE ports (J9574A 3800-48G-PoE+-4SFP+ Switch)	8,945.09	428.01	105	**984,176.00**
Cisco Catalyst 3750-X	4-Switch Stack with 72 GbE PoE and 72 GbE non-PoE ports, plus 8x 10GbE ports: (WS-C3750X-24-T-S, WS-C3750X-24-P-S, WS-C3750X-48-P-S and WS-C3750X-48-T-S)	65,571.01	1,682.39	35	**2,353,869.00**
	48 GbE PoE ports and 2x 10GbE ports (WS-C3750X-48P-S)	20,100.62	495.31	105	**2,162,573.00**
Juniper EX4200	4-Switch Stack with 72 GbE PoE and 72 GbE non-PoE ports, plus 8x 10GbE ports: (EX4200-24P, EX4200-48P, EX4200-24T, EX4200-48T)	56,871.19	774.01	35	**2,017,582.00**
	Standalone switch with 48 GbE PoE ports and 2x 10GbE ports (EX4200-48P)	17,710.76	2,339.03	105	**2,105,227.95**

Note:

A 5,000 port deployment is assumed to consist of:

- 35 units of a four-switch stack configuration with up to 72 PoE/PoE+ GbE ports, 72 non-PoE GbE ports and 2 10GbE ports, or
- 105 units of a switch configuration with 48 GbE PoE/PoE+ ports.
- For a detailed breakdown of the acquisition costs and power consumption test results used to derive the power and cooling costs, please refer to the companion document to this report titled "Tolly211127-Appendix-HP3800SeriesTCOVsCisco3750XandJuniperEX4200" available at www.tolly.com.

The acquisition costs, plus the power and cooling costs of the unit solution are extrapolated to a 5,000-port deployment size when multiplied by a factor of 35 for the 4-switch stack configuration, or by a factor of 105 for the 48-port standalone switch configuration.

DUT	Projected 3-year TCO			
	In a 4-Switch Stack	HP's TCO Savings	As a Standalone Switch	HP's TCO Savings
HP 3800	$1,310,686.30	–	$984,175.50	–
Cisco Catalyst 3750-X	$2,353,869.00	44%	$2,162,572.65	54%
Juniper EX4200	$2,017,582.00	35%	$2,105,227.95	53%

Source: Tolly, September 2011

Figure 7

Device(s) Under Test

Vendor	Software Version	Model Name	Module(s) Included
Hewlett-Packard Company	KA.15.03.0000x Ver 1:00:01	J9573A HP 3800-24G-PoE+-2SFP+ Switch	• J9577A HP 3800 4-Port Stacking Module • J9578A HP 0.5m Stacking Cable • J9665A HP 3800 1.0m Stacking Cable • J9580A HP X312 1000W 100-240VAC to 54 VDC PS • J9581A HP X311 400W 100-240VAC to 12VDC PS
		J9574A HP 3800-48G-PoE+-4SFP+ Switch	
		J9575A HP 3800-24G-2SFP+ Switch	
		J9576A HP 3800-48G-4SFP+ Switch	

Vendor	Software Version	Model Name	Module(s) Included
Juniper Networks, Inc.	Ver 11.1R3.5	EX4200-48T REV C	8 PoE Ports
			Built-in 4-Port 10GbE Module With 2 Ports Populated
		EX4200-48P REV C	48 PoE Ports
			Built-in 4-Port 10GbE Module With 2 Ports Populated
		EX4200-24P REV A	24 PoE Ports
			Built-in 4-Port 10GbE Module With 2 Ports Populated
		EX4200-24T REV A	8 PoE Ports
			Built-in 4-Port 10GbE Module With 2 Ports Populated

Vendor	Software Version	Model Name	Module(s) Included
Cisco Systems, Inc.	IOS Ver 12.2.53-SE2	WS-C3750X-24T-S v01	C3KX-PWR-350WAC PSU
			C3KX-NM-10G 10G Module With 2X SFP+
		WS-C3750X-48T-S V01	C3KX-PWR-350WAC PSU
			C3KX-NM-10G 10G Module With 2X SFP+
		WS-C3750X-24P-S V01	C3KX-PWR-715WAC PSU
			C3KX-NM-10G 10G Module With 2X SFP+
		WS-C3750X-48P-S V01	C3KX-PWR-715WAC PSU
			C3KX-NM-10G 10G Module With 2X SFP+

Source: Tolly, July 2011 Table 1

Interaction with Competitors

In accordance with Tolly's Fair Testing Charter, prior to the start of the testing, Tolly personnel invited representatives from Cisco and Juniper to participate in the project and provided details on the proposed tests and methodology. Cisco and Juniper representatives chose not to participate in this review.

For more information on the Tolly Fair Testing Charter, visit: http://www.tolly.com/FTC.aspx.

LAN to manage the switches, as well as to configure the Ixia traffic generator using Ixia IxAutomate application.

To measure the power consumption, the switches were connected to the power outlets with California Instruments power analyzers measuring the power draw.

Test Methodology

RFC 2889 Layer 2 Throughput

To measure the throughput, each switch under test was connected to the Ixia Optixia XM12 chassis using 144 GbE ports and up to eight 10GbE ports. The 144 GbE ports were configured in a full-mesh topology, meaning that each port on the switch sent traffic to, and received traffic from every other port in the switch. The 10GbE ports were connected in a separate full-mesh by themselves. All the ports on the switch were configured in the same IP subnet.

The test traffic consisted of bidirectional streams of Layer 2 traffic consisting of frames of 64-, 128-, 256-, 512-, 1024-, 1280-, 1518-, 2048-, 4096- and 9216-bytes, as specified by the RFC 2889.

The Ixia IxAutomate application was used to configure the Ixia ports to generate the test traffic, and to find the maximum zero-loss throughput using binary search algorithm. Each test was run for 60 seconds, and repeated three times to ensure repeatability of the results. Final results were announced as the average of the three test runs.

RFC 2889 Layer 2 Store-and-Forward Latency

The test bed setup and network topology for the latency tests was the same as that used for the throughput tests. The test traffic consisted of frames/packets ranging in size from 64 to 9216 bytes.

Since the Cisco switches exhibited throughput as low as 23%, engineers ran the latency tests at 10% line-rate on all the switches under test. The average "store and forward" latency was measured, and reported as the average of three test runs of 60 seconds duration each.

Microburst Tolerance Tests

To test the microburst tolerance of the devices under test, engineers connected the 48 GbE PoE/PoE+ ports on the switch to the Ixia chassis. The 48 GbE ports were split into two sets of 24 ports each, each set of ports then configured in a full-mesh. All the switches were configured with four queues, even though the HP switch supported 2, 4, or 8 queues.

The microburst traffic consisted of the standard frame sizes from 64-bytes to 9216-bytes at line-rate, and the number of frames in the microburst were generated using a custom command issued from Ixia IxAutomate. Thus, two microbursts at the given burst size were input to the device under test at the same time, and the no-loss microburst size was determined at each frame size. Tests were repeated three times to ensure repeatability of the results.

Power Consumption Tests

To measure the power consumption, engineers followed the methodology prescribed by two ATIS (Alliance for Telecommunications Industry Solutions) standards documents:

- ATIS-0600015.03.2009: Energy Efficiency for Telecommunication Equipment: Methodology for Measuring and Reporting For Router and Ethernet Switch Products, and
- ATIS-0600015.2009: Energy Efficiency for Telecommunications Equipment: Methodology for Measuring and Reporting - General Requirements

The power consumption of each product was measured at various load points: idle (0%), 10% and 100%. The test traffic consisted of an Internet Mix (IMIX) distribution of TCP packets of various sizes: 57% at 64-bytes, 7% at 570-bytes, 16% at 594-bytes and 20% at 1,518-bytes.

The final power consumption was reported as a weighted average calculated using the formula:

W_{ATIS} = 0.1*(Power draw at 0% load) + 0.8*(Power draw at 10% load) + 0.1*(Power draw at 100% load).

The formula above applies to access layer switches. Once again, all measurements were taken over a period of 60 seconds at each load level, and repeated three times to ensure repeatability of the results. Final results were reported as the average of the three runs.

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Visit Tolly on the Internet at: *http://www.tolly.com*

Test Equipment Summary

The Tolly Group gratefully acknowledges the providers of test equipment/software used in this project.

Vendor	Product	Web
Ixia	Chassis Type: Optixia XM12 Interfaces: 12 x 10Gbps 144x 1Gbps Software: IxAutomate 6.90 GA SP1	http://www.ixiacom.com/
Voltech	PM3000A Universal Power Analyzer	http://www.voltech.com/products/poweranalyzers/PM3000.aspx
California Instruments	5001i 5 kVA AC Power Source	http://www.elgar.com/products/i-iX_Series_II/i-iX_Series_II_Overview.htm

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