TEST REPORT

Tolly.

#216122

June 2016

Commissioned by
Aruba, an HPE Company

Aruba 3810M Switch Series

Competitive Performance, Power Consumption and TCO Evaluation versus Cisco Catalyst 3850

EXECUTIVE SUMMARY

The new generation of collaborative digital workplaces, a surge in IoT devices, and the increased speed of doing business on mobile are leading to questions regarding the readiness of network infrastructure. Aruba's mobile-first approach focuses on software-powered innovation to differentiate itself from traditional hardware-focused solutions — integrating the wired and wireless infrastructure, giving network operators insights into network performance, and enabling security amidst the growing number of mobile and IoT devices.

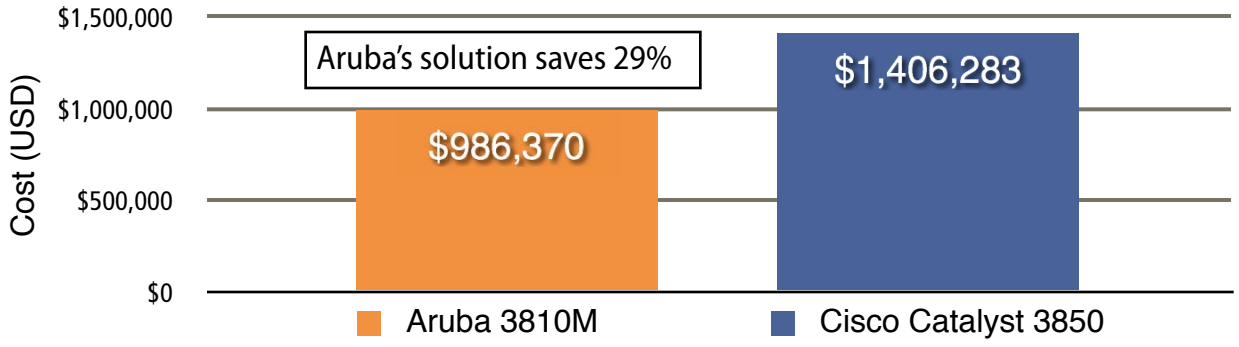
Aruba, a Hewlett Packard Enterprise company, commissioned Tolly to evaluate the performance, power consumption and total cost of ownership (TCO) of its stackable Aruba 3810M switch and compare that with the Cisco Catalyst 3850. The Aruba 3810M Switch Series delivered better performance with 51% lower latency than the Cisco Catalyst 3850 in standalone switch configuration across all frame/packet sizes tested in tests of Layer 2 switching. With respect to cost, the Aruba 3810M solution not only has lower initial costs but provides ongoing savings through more efficient use of power and cost-effective support.

THE BOTTOM LINE

Aruba 3810M Switch Series:

1. Provides 29% lower TCO than the Cisco 3850 in a 5,000 GbE port configuration
2. Delivers 69% lower average L2 5-member stack latency than the Cisco 3850
3. Delivers 51% lower average L2 standalone latency than the Cisco 3850
4. Cost-per-Gigabit that is 30% lower than the Cisco 3850
5. Includes full L3 features with no software licensing costs and a limited lifetime warranty

Three-Year Total Cost of Ownership (TCO) of a 5,000-Port Network Deployment
Aruba 3810M vs. Cisco Catalyst 3850



Note: Using fully-populated switches, each network contains 5,040 GbE ports. Pricing includes hardware and 3-year support costs sourced from CDW in April 2016 as well as power costs. See Tables 2 through 4 for details.

Source: Tolly, April 2016

Figure 1

Test Results

TCO for 5,000 Port Network

Elements of TCO

Network architects need to have a full understanding of both the initial and ongoing costs of deploying a LAN infrastructure. As part of this evaluation, Tolly engineers quantified the costs of building a network providing 5,000 users with Gigabit Ethernet (GbE) connectivity and 10GbE uplinks. The cost elements included: initial hardware costs, 3-year support costs and power costs.

Network Details and Costs

For each vendor, a deployment of 5,000 GbE ports would require 21 fully populated 5-member stacks. With each 5-member stack providing 240 GbE ports, the network would provide a total of 5,040 GbE ports.

For a single 5-member stack, the cost for the Cisco Catalyst 3850 configuration, including support for 3 years, is $65,098.72. The comparable Aruba solution configuration is significantly lower at $45,311.64. Extrapolated to the larger system and including the power costs, the Aruba solution cost of $986,370.42 is 29% lower than the Cisco Catalyst 3850 solution cost of $1,406,283.48. See Figure 1.

Performance

L2 & L3 IPv4 & IPv6 Standalone Performance

Tolly engineers benchmarked the performance of both switches using a single switch outfitted with the maximum capacity of GbE and 10GbE ports. Testing was conducted in a dual, full-mesh configuration. All GbE ports transmitted to every other port and all 10GbE ports communicated in the same fashion with all of the other 10GbE ports in the switch.

Aruba, an HPE Company

Aruba 3810M Switch Series

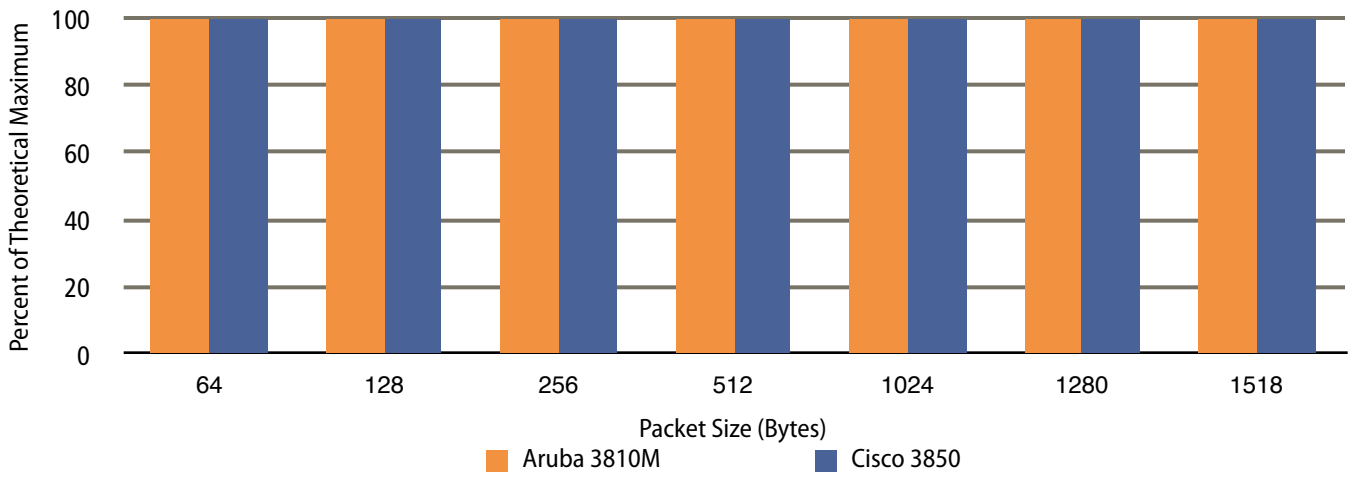
Performance, Power Consumption & TCO

Tested April 2016

Tests encompassed a range of traffic sizes from 64-bytes through 1518-bytes. Testing was conducted at layer 2 (switching) and layer 3 (routing). The L3 testing was conducted for both the IPv4 and IPv6 protocols. Layer 3 IPv6 throughput utilized 78-bytes (smallest IPv6 frame).

In all three test scenarios and at all packet sizes, the Aruba 3810M switch delivered

Standalone Layer 2 & Layer 3 (IPv4 and IPv6) Switch Throughput
Across 48 GbE and 4 10GbE Ports in a Dual-Mesh Configuration
(as reported by Spirent TestCenter 4.59)



Notes: Dual full mesh consisted of the GbE ports in one full mesh and the 10GbE ports in a separate full mesh. Layer 3 IPv6 throughput used 78-byte packets (smallest IPv6 packet). As results were identical in all three scenarios, a single graph depicts all results.

Source: Tolly, April 2016

Figure 2

100% of the theoretical maximum throughout at all packet sizes. The Cisco 3850 switch also delivered 100% throughput at all packet sizes. See Figure 2.

In addition, the Aruba 3810M provided 51% lower average L2 standalone latency than the Cisco 3850. See Figure 3.

Cost Per Gigabit

Tolly engineers evaluated the relative cost of the standalone switches by calculating the cost-per-gigabit-per-second of throughput.

As tested, the Aruba 3810M switch had a cost of $4,908.99 while the Cisco Systems switch had a cost of $7,013.99. This cost did not include any additional features or maintenance.

Dividing each of these values by the 48 wire-speed GbE ports gave a cost per Gigabit per second of throughput value of $146.12 for Cisco 3850 and $102.27 for Aruba. The Aruba solution is 30% lower cost than the Cisco solution. See Table 1.

Five-Member Stack Layer 2 GbE Full-Mesh Throughput

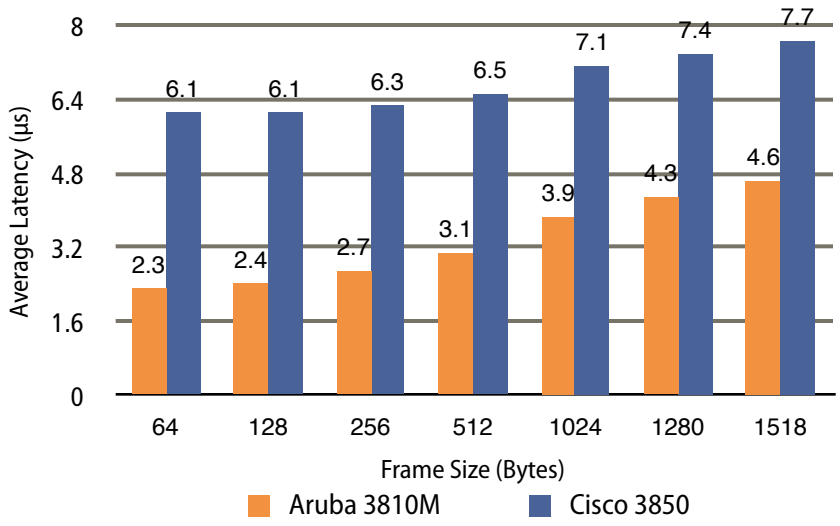
Performance tests focused on evaluating the aggregate throughput and latency exhibited by the Aruba and Cisco products under test as per the RFC 2889 methodology. The Aruba 3810M and Cisco Catalyst 3850 were configured with 240 GbE ports in full-mesh. This configuration allows each port to send and receive traffic from any other GbE port in the stack.

The Aruba 3810 switch stack offers a "full meshed" stacking topology, or every stack member has a direct stacking link to every other stack member, up to 5 members, as was tested in this evaluation. The Cisco 3850 switch series only offers a "ring" stack topology, which does not include a direct link between stack members. This increases the number of "hops" or stack members that data packets must go to traverse the stack.

Tests encompassed the entire range of packet sizes from 64-bytes through 1518-bytes. Testing was conducted at layer 2 (switching).

Tests show that the Aruba 3810M delivered 100% of the theoretical maximum throughout at all packet sizes. The Cisco Systems 3850 switch also delivered 100% throughput at all packet sizes. See Figure 4.

Standalone Layer 2 Gigabit Ethernet RFC 2544 Latency
Full Mesh Configuration Across 48 GbE Ports (5% Load)
(as reported by Spirent TestCenter 4.59)
Lower numbers are better



Source: Tolly, April 2016 Figure 3

Standalone Switch Cost per Gigabit/sec of Throughput

Solution	Cost per Gigabit of Throughput	Aruba Advantage vs. Cisco
Aruba 3810M (JL074A)	$102.27	30% savings with Aruba
Cisco 3850 (WS-C3850-48P-S)	$146.12	N/A

Note: Calculated by taking price of the system and dividing it by the system throughput. As both devices delivered wire-speed throughput at all frame/packet sizes, the throughput value was 48 Gbps.

Source: Tolly, April 2016 Table 1

Five-Member Stack Layer 2 GbE Full-Mesh Latency

Tolly engineers also measured the latency of each frame size for the GbE ports per the RFC 2544 methodology.

Tests encompassed the entire range of traffic sizes from 64-bytes through 1518-bytes. Testing was conducted at layer 2 (switching).

The Aruba 3810M provided 69% lower average L2 5-member stack latency than the Cisco 3850. See Figure 5.

Power Consumption

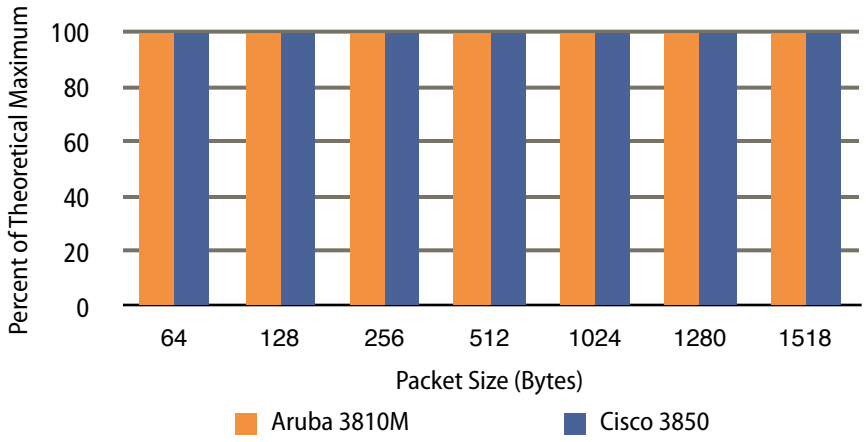
ATIS

Tolly engineers benchmarked the power consumption of each solution, outfitted with the maximum configuration of ports, according to the ATIS recommendations.

For Aruba, this configuration consisted of 240 GbE ports and 20 10GbE ports providing an aggregate throughput of 440 Gbps. For Cisco, this configuration consisted of 240 GbE ports and 20 10GbE ports providing an aggregate throughput of 440 Gbps.

In the ATIS calculation, a lower value is better. The ATIS results for the Cisco configuration was 711.91 compared to 632.31 from Aruba, making the Aruba system 11.2% more efficient. See Tables 2-4 for all power consumption and cost details.

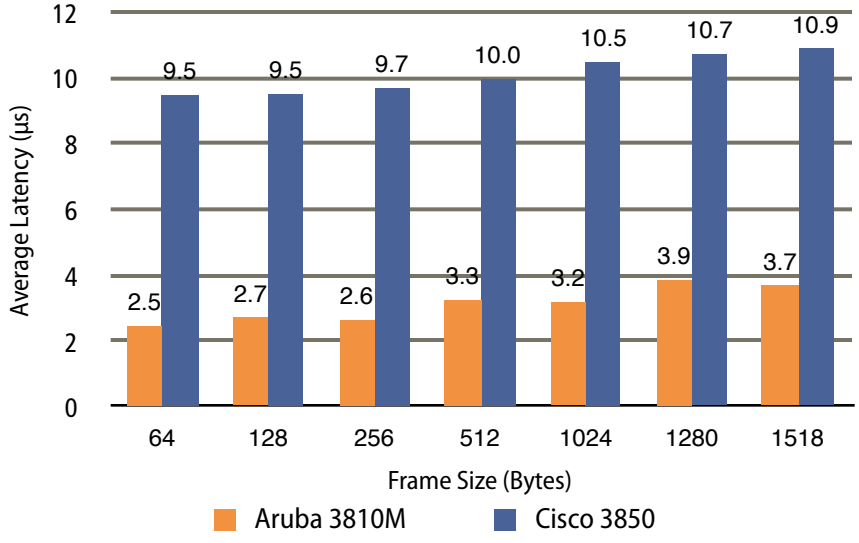
5-Member Stack Layer 2 Gigabit Ethernet RFC 2889 Throughput
Across 240 GbE Ports in Full-Mesh Configuration
(as reported by Spirent TestCenter 4.59)



Source: Tolly, April 2016

Figure 4

5-Member Stack Layer 2 Gigabit Ethernet RFC 2544 Latency
Full Mesh Configuration Across 240 GbE Ports (5% Load)
(as reported by Spirent TestCenter 4.59)
Lower numbers are better



Source: Tolly, April 2016

Figure 5

Five-Member Stack ATIS Power Consumption

Solution	Power Consumption at ATIS Traffic Loads (lower is better)			ATIS Weighted Average Power (W_{ATIS})	
	Idle	10%	100%		Aruba Advantage vs. Cisco
Aruba 3810M	624.97	630.27	656	632.31	11.18% savings with Aruba
Cisco 3850	711.5	709.3	733.2	711.91	N/A

Note: Systems tested with dual power supply. ATIS value is calculated by as 80% of the 10% load value plus 10% each of the idle and 100% load values. For idle, ports are active (green LED) but no traffic is running.

Five-Member Stack Power Consumption Calculations

Solution	# 1GbE Ports	# 10GbE Ports	Aggregate Throughput (Gbps)	ATIS Weighted Average Power (W_{ATIS})	Telecommunication Energy Efficiency Ratio (Gbps/W_{ATIS})	5-Member Stack Power Cost (OPEX) (3 Year)
Aruba 3810M	240	20	440	632.31	0.70	$1,658.38
Cisco 3850	240	20	440	711.91	0.62	$1,867.16

Note: Pricing for power: EIA.gov, January 2016 Commercial rate.

5,000-Port System Deployment Calculations

Solution	Port Configuration	# of 5-Member Stacks in 5,000-node network	# of 10GbE Ports	5-Member Stack Acquisition Cost (CAPEX) & 3 Year Support	5-Member Stack Power Cost (OPEX) (3 Year)	5,000 Port CAPEX	5,000 Port OPEX (Power)	Projected 3-year TCO of 5,000 port Layer-3 Deployment with 24x7x4 support	Cost Comparison: Aruba Advantage vs. Cisco
Aruba 3810M	240GbE PoE+, 20 10GbE	21	420	$45,311.64	$1,658.38	$951,544.44	$34,825.98	$986,370.42	Aruba is 29% lower cost than Cisco
Cisco 3850	240GbE PoE+, 20 10GbE	21	420	$65,098.72	$1,867.16	$1,367,073.12	$39,210.36	$1,406,283.48	N/A

Note: Using fully-populated switches, each network contains 5,040 GbE ports.

Source: Tolly, April 2016

Tables 2-4

Solutions Under Test

Standalone Performance

	Aruba 3810M	Catalyst 3850
Device Under Test	1 x Aruba 3810M 48G PoE+ 1-slot Switch (JL074A)	1 x Cisco Catalyst 3850 48 Gigabit Ethernet Switch UPOE (WS-C3850-48U-S)
Power Supplies	1 x Aruba X372 54VDC 1050W 110-240VAC Power Supply (JL087A)	1 x Cisco 1100W Hot Plug/Redundant Power Supply for Catalyst 3850 (PWR-C1-1100WAC)
Total Port Count	48GbE and 4 10GbE Ports	48GbE and 4 10GbE Ports
Software Version	KB.16.01.0004	IOS-XE 03.06.04.E

Five-Member Stack Performance

	Aruba 3810M	Catalyst 3850
Device Under Test	4 x Aruba 3810M 48G PoE+ 1-slot Switch (JL074A) 1x Aruba 3810M 48G 1-slot Switch (JL072A)	1 x Cisco Catalyst 3850 48 Gigabit Ethernet Switch UPOE (WS-C3850-48U-S) 4 x Cisco Catalyst 3850 48 Gigabit Ethernet Switch PoE + (WS-C3850-48P-S)
Power Supplies	4 x Aruba X372 54VDC 1050W 110-240VAC Power Supply (JL087A) 1x Aruba X371 12VDC 250W 100-240VAC Power Supply (JL085A)	5 x Cisco 1100W Hot Plug/Redundant Power Supply for Catalyst 3850 (PWR-C1-1100WAC)
Total Port Count	240 GbE Ports	240 GbE Ports
Software Version	KB.16.01.0004	IOS-XE 03.06.04.E

Source: Tolly, April 2016 Tables 5-6

Aruba 3810M Series Feature Comparison

Coverage Highlights

As Provided by Aruba. Not Validated by Tolly.

Solution	Stack Members	Max. 1GbE Ports	Max. 40GbE Ports/Line Rate	Throughput 24/48 Ports	Stack Without License	No License for Layer 3 Features	Warranty	SDN	List Price 48PoE+ with 4xSFP+
Aruba 3810M	10	480	20	95.2/190.5	✔	✔	Limited Lifetime	Industry-Standard OpenFlow	$9,500 USD
Cisco 3850	9	432	18	68.4/130.9	License required	License required	Enhanced Lifetime	OpenFlow is supported after IOSXE 3.7.3	$15,400 USD

Note: These features were not tested by Tolly as part of this evaluation.

Source: Aruba, April 2016 Table 7

Cost Details: Aruba 3810M Series Switch of 240 GbE, PoE+ and 20 10GbE Ports

Item	Product SKU	Description	Qty	Unit Price (US $)	Ext. Price (US $)	Subtotal (US $)
Hardware	JL074A	Aruba 3810M 48G PoE+ 1-slot Switch	5	$4,908.99	$24,544.95	$42,354.65
	JL087A	Aruba X372 54VDC 1050W 110-240VAC Power Supply	10	$666.99	$6,669.90	
	JL083A	Aruba 3810M 4SFP+ Module	5	$868.99	$4,344.95	
	JL084A	Aruba - network stacking module	5	$892.99	$4,464.95	
	J9578A	HPE stacking cable - 1.6 ft	10	$232.99	$2,329.90	
Support	U7DH8E	Support Cost for 3-year 24x7	1	$2,956.99	$2,956.99	$2,956.99
Total Cost of a Switch with 240 PoE+ GbE and 24 20 GbE ports with 3-year 24x7x4hr Support						$45,311.64

Cost Details: Cisco Catalyst 3850 Series Switch of 240GbE, PoE+ and 20 10GbE Ports

Item	Product SKU	Description	Qty	Unit Price (US $)	Ext. Price (US $)	Subtotal (US $)
Hardware	WS-C3850-48P-S	Cisco Catalyst 3850 48GbE Ports Managed Switch (PoE+)	5	$7,013.99	$35,069.95	$61,159.75
	PWR-C1-1100WAC	Cisco 1100W Hot Plug/Redundant Power Supply for Catalyst 3850-48F-E	10	$1,104.99	$11,049.90	
	C3850-NM-4-10G=	Cisco Expansion Module for Catalyst 3850-24	5	$2,859.99	$14,299.95	
	STACK-T1-1M=	Cisco 3.3' StackWise 480 Stacking Cable	5	$147.99	$739.95	
Support	CON-SNTP-WSC388PS	Cisco SMARTnet extended service agreement	3	$1,312.99	$3,938.97	$3,938.97
Total Cost of a Switch with 240 PoE+ GbE and 20 10 GbE ports with 3-year 24x7x4hr Support						$65,098.72

Note: Hardware and support pricing from CDW in US dollars, April 2016.

Source: Aruba, Tolly, April 2016 Tables 8-9

Telecommunications Energy Efficiency Ratio (TEER)

The ATIS results can also be used to calculate the TEER (where higher results are better). According to ATIS, "The [TEER] efficiency standards are specific to equipment type, network location and classification. Normalizing these ratings by functionality enables "apples-to-apples" equipment comparison. This systemized assessment results in repeatable and comparable energy consumption measurement."

Where the TEER value for the Cisco solution is .70 the TEER value for the Aruba 3810M solution is 13% better at .62. See Table 3.

Select Features

Boot Time

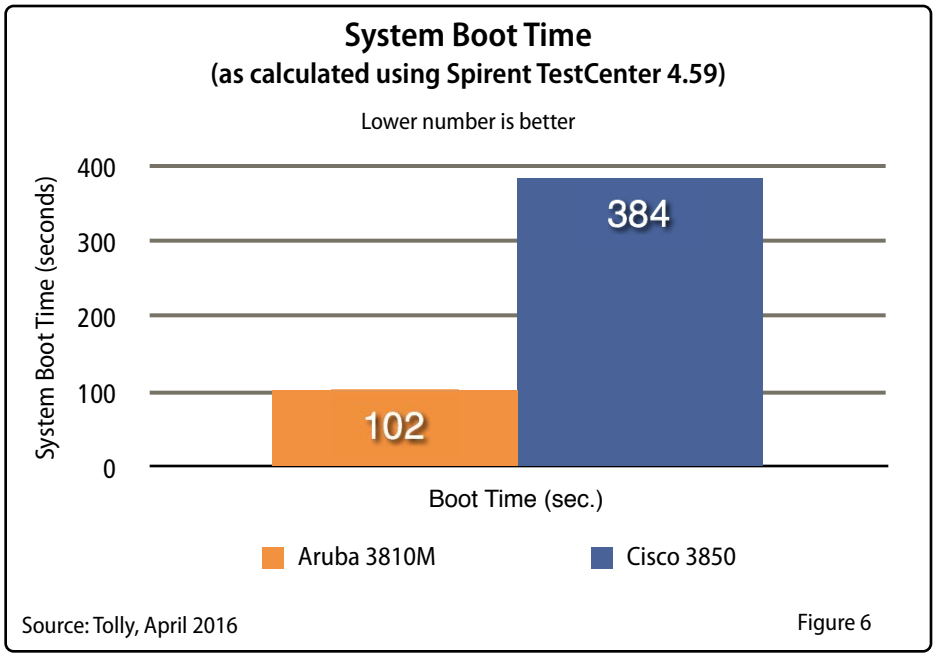
Tolly engineers evaluated the time (seconds) required to boot a standalone Aruba 3810M and the Cisco Catalyst 3850 after reloading the switch, which was

sending 2Gb of traffic (used 2GbE ports on each switch).

The Aruba 3810M was able to reboot and start forwarding traffic again in less than 2 minutes while the Cisco Catalyst 3850 required over 6 minutes. See Figure 6.

Quality of Service (QoS)

Tolly engineers verified that each solution supports Layer 2 QoS on a standalone switch. Streams with different 802.1p priorities had different throughput when passing through a stacking cable.



Source: Tolly, April 2016

Figure 6

Test Setup & Methodology

Single Unit & 5-Member Stack Throughput/Latency

Performance Test Environment

Performance tests (standalone and 5-member stack) were performed using Spirent's TestCenter 4.59 test tool, and 2x Spirent SPT-9000 Chassis, populated with 12-port 1GbE modules and 8 port 10GbE modules. All tests were run using Spirent TestCenter 4.59 on a Microsoft Windows 8 system. All switches tested were similarly configured.

RFC 2889 Throughput

To measure the standalone throughput, the Aruba and Cisco switch was connected to 1x Spirent chassis using 48 GbE ports and four 10GbE ports. All GbE ports were configured in a full-mesh topology, meaning that each GbE port on the switch sent traffic to, and received traffic from every other GbE port in the switch. The four 10GbE ports also used full-mesh topology.

Both Layer 2 and Layer 3 (IPv4 and IPv6) throughput were tested.

For the 5-member stack throughput test, the Aruba and Cisco switch was connected to 2x Spirent chassis using 240 GbE ports. All GbE ports were configured in a full-mesh topology, meaning that each GbE port on the switch sent traffic to, and received traffic from every other GbE port in the switch.

The test traffic contained fully-meshed streams of Layer 2/3 (IPv4 only) traffic consisting of frames/packets of 64, 128-, 256-, 512-, 1024-, 1280-, and 1518-bytes, as specified by RFC 2889. Layer 3 IPv6 throughput utilized 78-bytes (smallest IPv6 frame).

RFC 2544 Latency

To measure standalone latency, the Aruba and Cisco switch was connected to 1x

Test Equipment Summary

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

Vendor	Product	Web
Ixia	**Optixia XM12** **Software: IxNetwork 8.01 EA**	http://www.ixiacom.com
Spirent Communications	**2x SPT-9000 Chassis** **Software: TestCenter 4.59**	http://www.spirent.com

Spirent chassis using 48 GbE ports. All GbE ports were configured in a full-mesh topology, meaning that each port on the switch sent traffic to, and received traffic from one another port in the switch. Layer 2 was tested.

To measure 5-member stack latency, the Aruba and Cisco switch was connected to 2x Spirent chassis using 240 GbE ports. All GbE ports were configured in a full-mesh topology, meaning that each GbE port on the switch sent traffic to, and received traffic from one another port in the switch. Layer 2 was tested.

The test traffic contained fully-meshed streams of Layer 2 traffic consisting of frames/packets of 64-, 128-, 256-, 512-, 1024-, 1280-, and 1518-bytes, as specified by RFC 2544.

Power Consumption Tests for TCO Analysis

To measure the power consumption, engineers used the same configuration on the Aruba 3810M and Cisco Catalyst 3850. Each switch had 240 GbE ports in a snake configuration and (20 for Aruba, 20 for Cisco) 10GbE ports in a second snake configuration, passing bidirectional traffic. Power consumption was measured by a Voltech PM3000A Universal Power Analyzer. For this test, Tolly engineers utilized 1x Ixia Optixia XM12 chassis.

ATIS Power Consumption

Tolly 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:

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

The formula above applies to access layer switches. Once again, all measurements were taken over a period of two minutes 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.

Telecommunications Energy Efficiency Ratio (TEER)

The TEER (Telecommunications Energy Efficiency Ratio) was developed by the Alliance for Telecommunications Industry Standards (ATIS) as a measure of network efficiency. The standard provides a comprehensive methodology for measuring and reporting energy consumption of telecommunications equipment.

Power Costs

Power costs were calculated using the January 2016 "commercial" rate of $00.0998 per kilowatt hour as determined by the U.S. Energy Information Administration (http://www.eia.gov).

Boot Time

The boot time on the Aruba 3810M and Cisco Catalyst 3850 was measured using Spirent TestCenter 4.59. Tolly engineers sent L2 traffic of 64-bytes at 100% load for 10 minutes. Two GbE ports on each switch was used for the test. To calculate the boot time Tolly engineers divided the frame loss by the frame rate. Final results were reported as the average of the three runs.

About Tolly

The Tolly Group companies have been delivering world-class IT services for more than 25 years. Tolly is a leading global provider of third-party validation services for vendors of IT products, components and services.

You can reach the company by E-mail at sales@tolly.com, or by telephone at +1 561.391.5610.

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

Interaction with Competitors

In accordance with Tolly's Fair Testing Charter, Tolly personnel invited representatives from Cisco Systems, Inc. to participate in the test. Cisco Systems did not respond to the invitation.

For more information on the Tolly Fair Testing Charter, visit:

http://www.tolly.com/FTC.aspx

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