Detailed Lab Testing Report
DR120911

SMB Managed Stackable Switches Comparison
Cisco
D-Link
Hewlett-Packard
Netgear

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Miercom

www.miercom.com

Contents

1.0 Executive Summary

This report discusses the findings of a recent test of web-manageable switch products for the SMB (Small and Medium Business) market space. It specifically compares and contrasts the features and performance of the Cisco SF500, SG500, and SG500X series of switches with similar products offered by HP, D-Link, and Netgear.

Overall, we were impressed with the comprehensive set of features, performance, power efficiency, and ease-of-use of the Cisco switches. Specifically, we found that Cisco delivered the highest capacity and scalability of configuration parameters including VLANs, MACs, ACLs, and IP routes. The Cisco switches provided the best resiliency when subjected to a DoS attack. Cisco switches can also be seen as more economical when measured using normalized pricing based on Price per gigabit and Price per PoE Watt. In addition, they were the most efficient both in terms of overall energy consumption, and the energy saving capabilities provided. The Cisco switches included in this test were the easiest to configure and implement, forwarded line rate full mesh traffic at all frame sizes with zero packet loss, and provided the most extensive support for IPv6 transitions.

The primary area of focus discussed in this report is switch stacking. Switch vendors have designed their switches with stacking capabilities for simplified network administration, scalability, resiliency and flexibility. Stackable switches should have the ability to be accessed from a single point for configuration purposes, by either GUI or CLI. Stackable switches can be added to an existing stack to increase port density. A switch stack should be resilient. This is in contrast with switch clustering, which does not operate as a single entity. Stackable switches should be able to be configured for use in a stack or as a standalone switch. These four key areas were tested, with results compared between the four vendors.

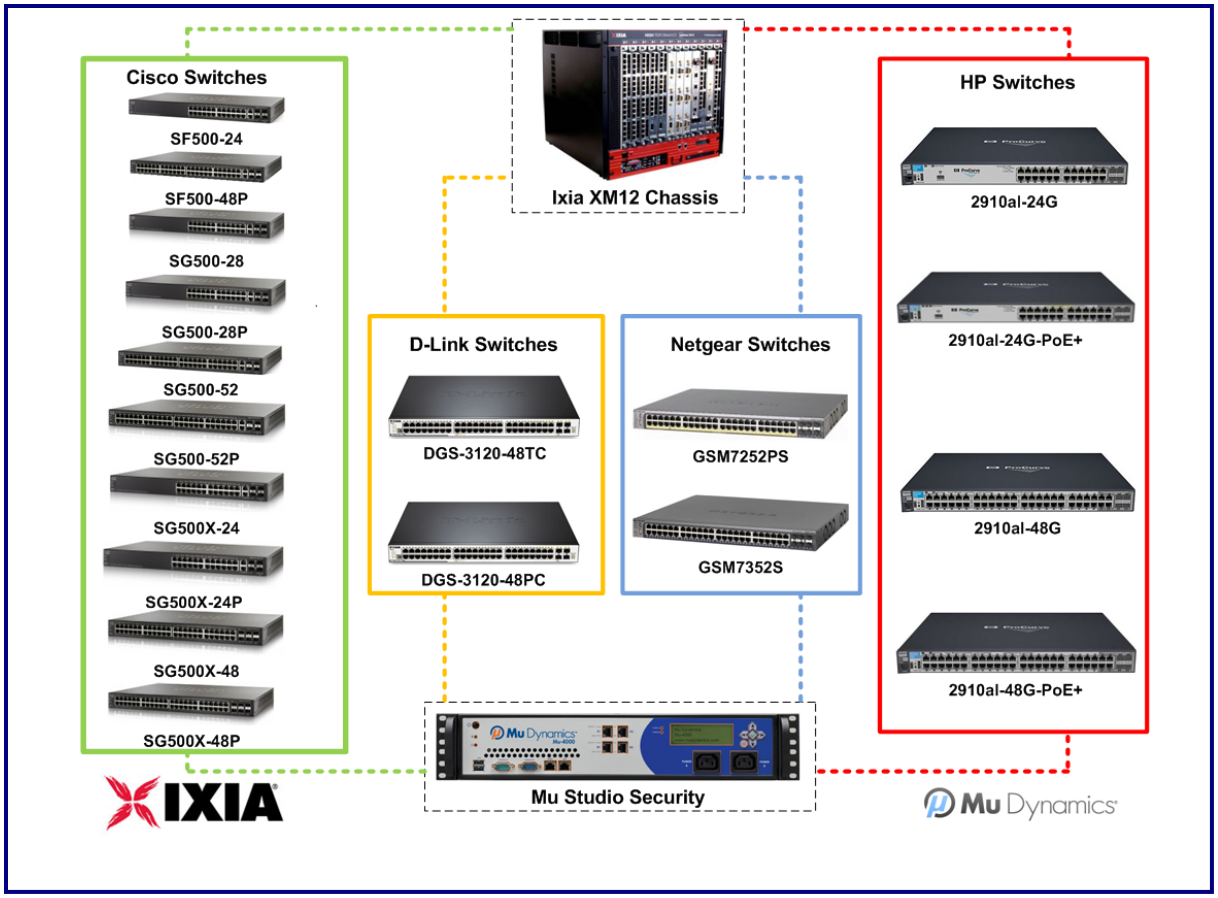
This report sponsored by Cisco Systems, Inc., was produced with data obtained completely and independently as part of the Miercom Ethernet Switch Industry Assessment in which all vendors have equal opportunity to participate and contribute to the test methodology. All vendors involved in these tests were afforded opportunity to represent their products, and vendors still have opportunity to actively participate in the Industry Assessment and challenge any test findings by lab testing.

Bottom line, the Cisco series switches included in this report have demonstrated superiority in the SMB switch market for the areas selected in this analysis.

Rob Smithers

CEO Miercom

1.1 Test Bed Diagram



1.2 Test Equipment used

Ixia (www.ixiacom.com) is an industry leader in IP performance testing. Real-world traffic is generated by Ixia's XM12 chassis using test applications, principally IxAutomate for layer 2-3 switching and routing traffic.

Mu Studio Security (www.mudynamics.com) provides a complete service assurance solution for determining the reliability, availability and security of IP-based applications and services. The Mu solution is highly automated, with lights-out fault isolation. Speeding the remediation of software flaws, Mu Studio Security provides actionable reports and complete data on any faults. Mu-based testing is managed via a variety of interfaces, including a highly visual Web-based graphical user interface. Testing can also be remotely controlled using REST- or XML-based APIs for integration into common laboratory automation frameworks such as HPQC or STAF.

2.0 Description of Switches

All of the switches in this report are for the SMB market. Each switch has different specifications and features such as 24, 28, 48 or 52 ports; with additional gigabit copper or fiber uplinks. Some have either dedicated stacking ports or SFP+ ports for stacking. The latest firmware was used during testing. A description of the switches is listed below for comparison.

Cisco (SF500, SG500, SG500X series)

Generally, all of the Cisco switches tested had some form of energy saving features. Each switch supported Energy Detect, Short Reach, and the option to disable port LEDs. EEE (Energy Efficient Ethernet) was also supported on the Cisco switches, except for the SF500 series switches. The capabilities of these three features are thoroughly discussed in the energy efficiency section on page 21.

Additionally the SF500 and SG500-28 series switches are designed without fans, increasing the overall energy efficiency.

Stacking indicators are on the front panel for quick stack member role identification. Cisco switches allow a mix of 10/100 and Gigabit switches in the same stack, which is not supported by the competitive products from HP, Netgear and D-Link.

Both Layer 2 and Layer 3 features and traffic handling are supported. POE+ is supported on all ports in the POE models for Cisco.

5G stack links are supported by the SF500 and SG500 while the SG500X has 10G stack links. Cisco Stack ports can also be used as network ports providing the flexibility to use the switches in standalone mode without any loss of ports. This also delivers the most cost-effective stacking. CLI and GUI are available for configuration.

Model	Product Class	PoE 802.3at and 802.3af	Firmware Version	Uplinks	Energy Save
SF500-24	10/100	N	1.2.7.76	2 Combo GbE 2 - 1G/5G SFP	Y
SF500-48P	10/100	Y	1.2.7.76	2 Combo GbE 2 - 1G/5G SFP	Y
SG500-28	GbE	N	1.2.7.76	2 Combo GbE 2 - 1G/5G SFP	Y
SG500-28P	GbE	Y	1.2.7.76	2 Combo GbE 2 - 1G/5G SFP	Y
SG500-52	GbE	N	1.2.7.76	2 Combo GbE 2 - 1G/5G SFP	Y
SG500-52P	GbE	Y	1.2.7.76	2 Combo GbE 2 - 1G/5G SFP	Y
SG500X-24	GbE	N	1.2.7.76	4 – 10G SFP+	Y
SG500X-24P	GbE	Y	1.2.7.76	4 – 10G SFP+	Y
SG500X-48	GbE	N	1.2.7.76	4 – 10G SFP+	Y
SG500X-48P	GbE	Y	1.2.7.76	4 – 10G SFP+	Y

Netgear (GSM7252PS, GSM7352S series)

Both 48 port switches were equipped with dedicated stacking ports and two 10G SFP+ ports. Stacking indicators on the front panel shows the unit number and stack member role.

PoE+ is supported on the GSM7252PS switch on the first eight ports with standard PoE on the remaining ports.

PoE+ ports provide up to 30 watts per port, while PoE ports can provide up to 15.4 watts. Neither of the switches supports energy saving features.

Both Layer 2 and Layer 3 features and traffic handling are supported.

CLI and GUI are available for configuration.

Model	Product Class	PoE	Firmware Version	Uplinks	Energy Save
GSM7252PS	GbE	Y	8.0.3.25	4 Combo GbE 2 10G SFP+	N
GSM7352S	GbE	N	8.0.3.25	4 Combo GbE 2 10G SFP+	N

HP (2910al-24G, 2910al-48G series)

The 2910al series switches had either 24 or 48 ports, with or without PoE.

The front panel did not have any indicators for stacking because these switches do not support stacking in the classical sense as supported by the Cisco, Netgear, and D-Link switches in this test. True Stacking delivers a Unified Management, Control, and Forwarding plane. With these HP switches, there is some unification of the Management plane (all switches can be reached through a single IP address), but each unit in their “stack” runs its own instance of Spanning Tree, SNMP agent, RMON agent, etc. Also, in HPs implementation, ARP, MAC Address, and VLAN tables are not synchronized across the stack but each are maintained independently. On a true stack, port mirroring and link aggregation can be implemented across units in a stack but this is not possible with the 2910al HP switches while they are supported in the Cisco, Netgear and D-Link switches in this test. See section 3 for additional descriptions of Stacking.

Both Layer 2 and Layer 3 features and traffic handling are supported.

Neither of the switches in the series support energy saving features.

PoE is supported on all ports.

GUI must be enabled from the CLI by assigning an IP address for access.

Model #	Product Class	PoE	Firmware Version	Uplinks	Energy Save
2910al-24G	GbE	N	W.14.49	4 – Combo 10/100/1000	N
2910al-24G-PoE+	GbE	Y	W.14.49	4 – Combo 10/100/1000	N
2910al-48G	GbE	N	W.14.49	4 – Combo 10/100/1000	N
2910al-48G-PoE+	GbE	Y	W.14.49	4 – Combo 10/100/1000	N

D-Link (DGS-3120 series)

Both 48 port switches were equipped with dedicated stacking ports and four combo GbE uplinks.

The front panel has stacking indicators, showing the unit number and the stack member role.

Both Layer 2 and Layer 3 features and traffic handling are supported.

CLI and GUI are available for configuration.

Energy saving features are supported and are discussed on Page 21

Model #	Product Class	PoE	Firmware Version	Uplinks	Energy Save
DGS-3120-48TC	GbE	N	R2.00.010	4 combo GbE	Y
DGS-3120-48PC	GbE	Y	R2.00.010	4 combo GbE	Y

2.1 Scalability and Capacity

With networks growing rapidly, switches are built with bigger MAC tables, while supporting more VLAN entries, ACL rules and IP routes. These four features were compared between the different switch categories. Product datasheets were used to obtain capacity values.

Switch Capacity

		Layer 2		Layer 3	
Configuration	**Model**	**MAC Table Size**	**MAX VLANs**	**ACL Rules**	**IP Routes**
24-port 10/100	Cisco SF500-24	16,384	4,096	2,000	128
48-port 10/100	Cisco SF500-48P	16,384	4,096	2,000	128
24/28-port Gigabit	Cisco SG500X-24	16,384	3,000	2,000	128
	Cisco SG500X-24P	16,384	3,000	2,000	128
	Cisco SG500-28	16,384	4,096	2,000	128
	Cisco SG500-28P	16,384	4,096	2,000	128
	HP 2910al-24G	16,384	256	512	256
	HP 2910al-24G-PoE+	16,384	256	512	256
48/52-port Gigabit	Cisco SG500X-48	16,384	3,000	2,000	128
	Cisco SG500X-48P	16,384	3,000	2,000	128
	Cisco SG500-52	16,384	4,096	2,000	128
	Cisco SG500-52P	16,384	4,096	2,000	128
	D-Link DGS-3120-48PC	16,384	4,000	512	512
	D-Link DGS-3120-48TC	16,384	4,000	512	512
	HP 2910al-48G	16,384	256	512	256
	HP 2910al-48G-PoE+	16,384	256	512	256
	Netgear GSM7252PS	8,192	1,024	1,024	224
	Netgear GSM7352S	8,192	4,000	1,024	480

The MAC table size ranged from 8,192 to 16,384, ACL rules ranged from 512 to 2,000, VLANs ranged from 256 to 4,096, and IP routes ranged from 128 to 480 across all switches.

All of the switches supported 16,384 MAC addresses, with the exception of Netgear which supports 8,192.

Cisco switches had the highest VLAN capacity (4,096), highest ACL rules (2,000).

Netgear switches supported the most IP routes at 480.

3.0 Stacking Configuration and Performance

SMB stackable switches were tested for performance when in a stacking configuration. This was executed by running partially meshed traffic through the stack which determined the bandwidth the stack could achieve. Other testing included configuration on the switch master and verifying that configuration is saved when the master switch is removed.

When a stack is configured as a ring, each of the switches can communicate with others through one of the two stack ports. A ring setup allows for maximum uptime with little or no loss of traffic. Another stack configuration is chain topology. A chain topology only allows one way communication with the next switch. When a cable is removed or fails with active traffic, the traffic would stop. A ring topology prevents this type of failure and is essential for high availability and minimal traffic loss in a switch stack.

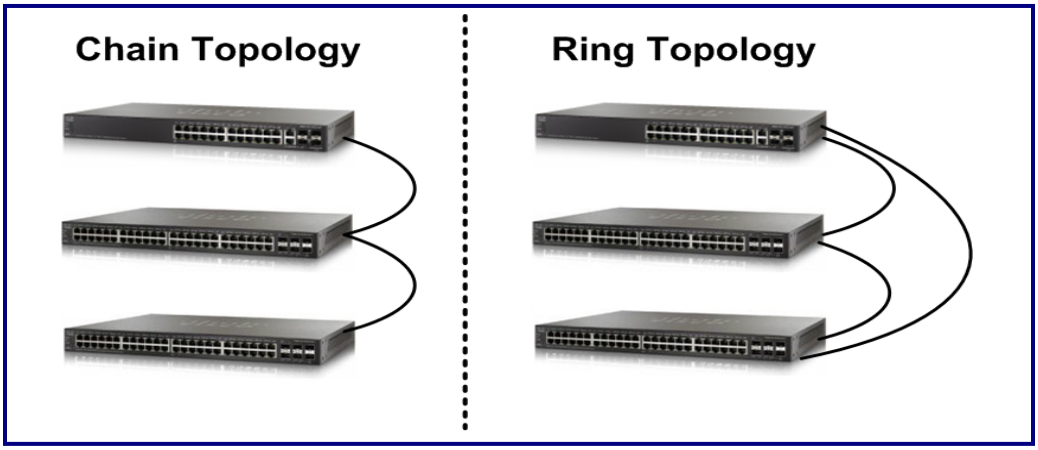
A true Stacking architecture delivers a Unified Management, Control, and Forwarding plane. With clustering (sometimes called stacking as in the case of the HP switches), there is some unification of the Management plane (all switches can be reached through a single IP address), but each unit in the “stack” runs its own instance of Spanning Tree, SNMP agent, RMON agent, etc. Also, in HPs implementation, ARP, MAC Address, and VLAN tables are not synchronized across the stack but each are maintained independently. On a true stack, port mirroring and link aggregation can be implemented across units in a stack. Cisco, Netgear and D-Link provided this functionality, but this is not possible with the HP switches.

3.1 Stack Configuration

Cisco

With true stacking, the stack is formed automatically. The number of stacking cables required is equal to the number of switches (when configured in a Chain topology) and one additional when configured in a ring topology. Once powered up, the switches determine which will be the stack master automatically based on the lowest MAC address. The remaining switches become the secondary and the third units. The second unit is also assigned as the secondary master, in the event of a primary master failure. The user can also manually define the master, backup, and slave units.

Chain vs. Ring Topology

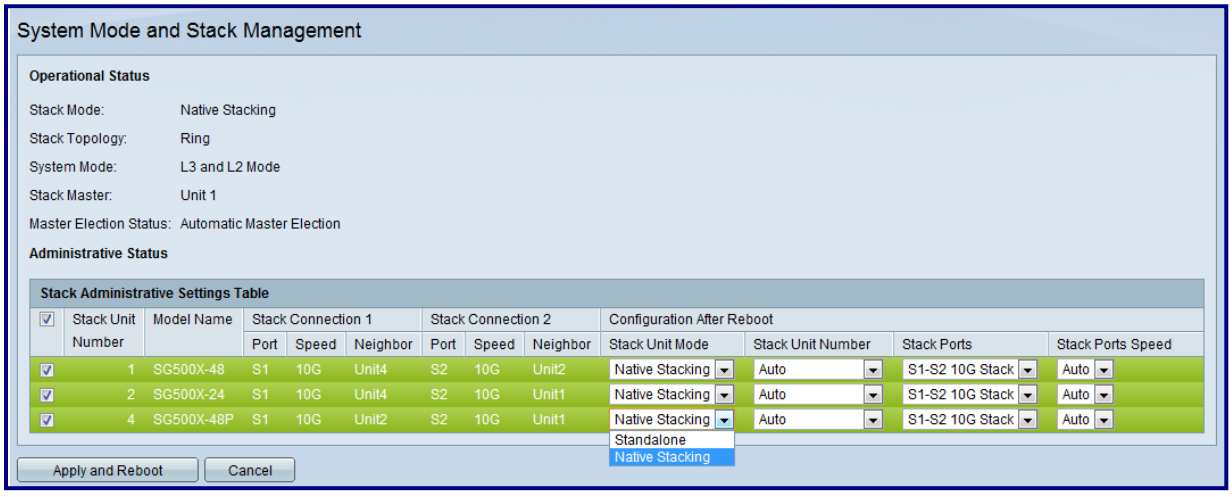


Ring topology is a resilient stacking configuration, which provides high availability and minimal traffic loss through hardware failover. Clustering supports failover via software (Spanning Tree).

Stack performance was a key metric in testing. But how does the stack perform, in terms of configuration and ease-of-use? The Cisco stack allows for a single point of management via GUI or CLI. Configurations can be made through the stack master and are instantly synchronized with the secondary master. Thus if the secondary master becomes the primary stack master it contains all configurations previously made.

For proper functionality of the Cisco stack, all stacked switches must have the same software code. If a new switch is added without the proper SW code, the master will automatically download and install the correct software, and reboot the individual switch afterwards.

Cisco Stacking Configuration



Cisco GUI gives users access to stacking configurations from the primary master switch.

Options for the stacking configuration are displayed above. Choices include standalone or native stacking, and manual assignment of unit numbers to switches. Stack ports can be configured for port speeds of auto, 1G, 5G or 10G.

A VLAN configuration screen allows VLAN configuration on the stack. Ports are assigned to VLANs by toggling between the different switches. This can be configured within one switch GUI via the stack master. The GUI, CLI, and front panel LEDs show the stack master switch.

To test the stack resiliency, two VLANs were created on the stack master. The configuration for VLAN 2 was saved after configuration. VLAN 3 was created, but the configuration was not saved. After removing the stack master, the secondary master took over its role. Both VLAN2 and VLAN3 were retained. It is not necessary to save the running configuration.

When the stack master was removed, the secondary master instantly took over the role of master. The GUI and CLI were checked to verify which switch was the master and which was secondary. The front panel of the switch also identifies the role of the switch in the stack and what the assigned member number is.

Another useful feature was the Full Stack device view, which gave data pertaining to port usage, and stack member roles. Port configuration changes and statistics are available in the Full Stack view with drill down menu options.

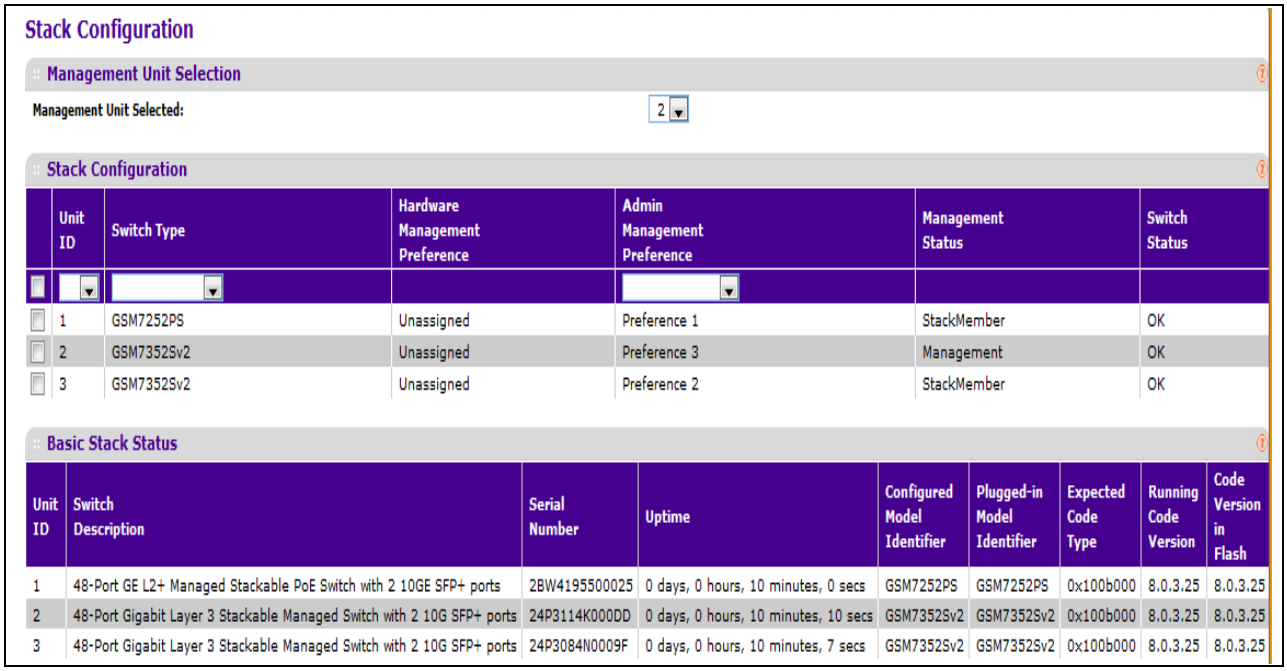
Configuration of QoS, ACLs, and others are performed once for the entire stack.

The GUI for the 500 series switches tested here is identical to the 200 and 300 series Switches tested previously by Miercom, see report DR120119.

Netgear

Netgear switches were configured in a ring topology for maximum resiliency and uptime. Equipped with dedicated stacking ports, these switches are capable of achieving up to 12 Gbps throughput across each stack link. When the stack master was removed, the secondary master instantly took over the role of master. GUI and CLI were checked to verify which switch was the master and secondary. The front panel of the switch also identifies the role of the switch in the stack and what the assigned member number is.

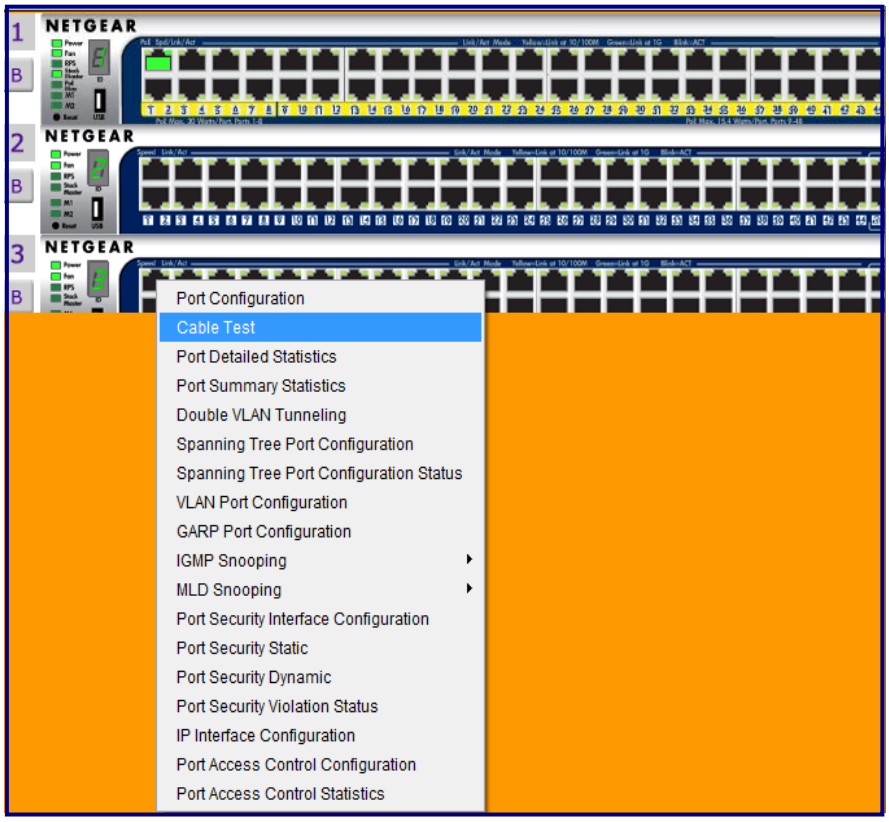
Netgear Stacking Configuration



Users can use a GUI to configure all stack members from the stack master.

A configuration page allows users to make changes to the stack by assigning switches different preferences, changing the management unit, and unit ID. Additional information such as the switch description, serial number, uptime, model, and the software version are provided on this page. Another useful feature was the full stack device view, which gave data pertaining to port usage, and stack member roles. Port configuration changes and statistics are available in the Full Stack view with drill down menu options.

Netgear Full Stack View



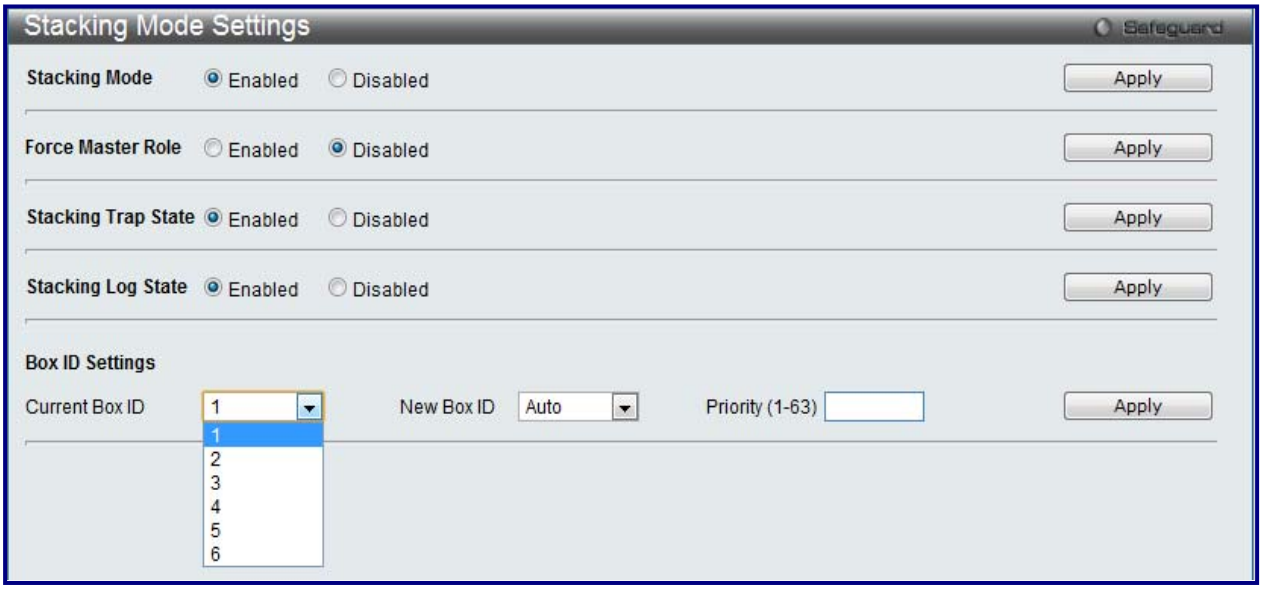
Netgear has a full stack view, allowing per port configuration changes.

To test the stacks resiliency, two VLANs were created on the stack master. The configuration for VLAN 2 was saved after configuration. VLAN 3 was created, but the configuration was not saved. After removing the stack master, the secondary master took over its role. VLAN 2 was saved; but VLAN 3 was lost from the configuration. In order for the stack to be completely synchronized, the running configuration needs to be saved.

D-Link

D-Link switches are designed with dedicated stacking ports capable of achieving up to 13 Gbps throughput across each stack link. The master unit is elected automatically by the stack through a process which determines the lowest MAC address. A switch can also be manually configured to be the master by assigning it a higher priority before plugging it into a stack. The front panel of the switch has indicators which display the role of each switch. The master displays the ID and an uppercase H. The backup master displays the ID and a lowercase h. The remaining switches in the stack are slaves. When the primary master is removed from the stack, the backup master instantly took over the primary master role. However, when the primary master was connected back into the stack, the current primary master and the slave were both automatically rebooted. The primary master became the master of the stack, the second unit became the backup and the third unit became a slave.

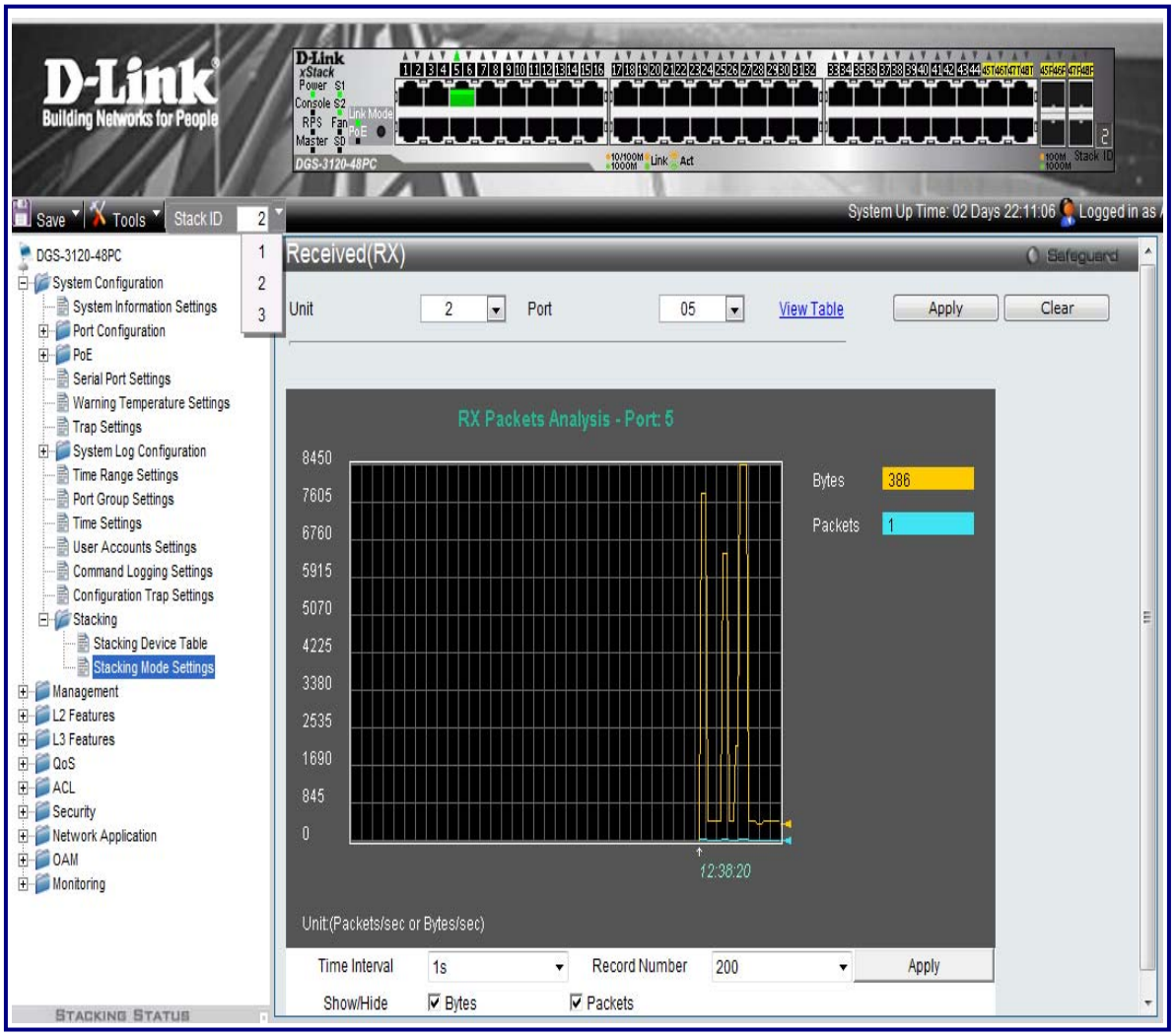
D-Link Stack Configuration



The D-Link GUI gives users access to multiple stacking configurations.

The D-Link stack configuration screen allows changing priorities on switches in the stack. Users have the choice to make a switch functional in standalone mode or in stacking mode. Force master can be enabled on a switch; a reboot is required for this configuration.

D-Link Stack



GUI allows users to switch between different switches in the stack for configuration.

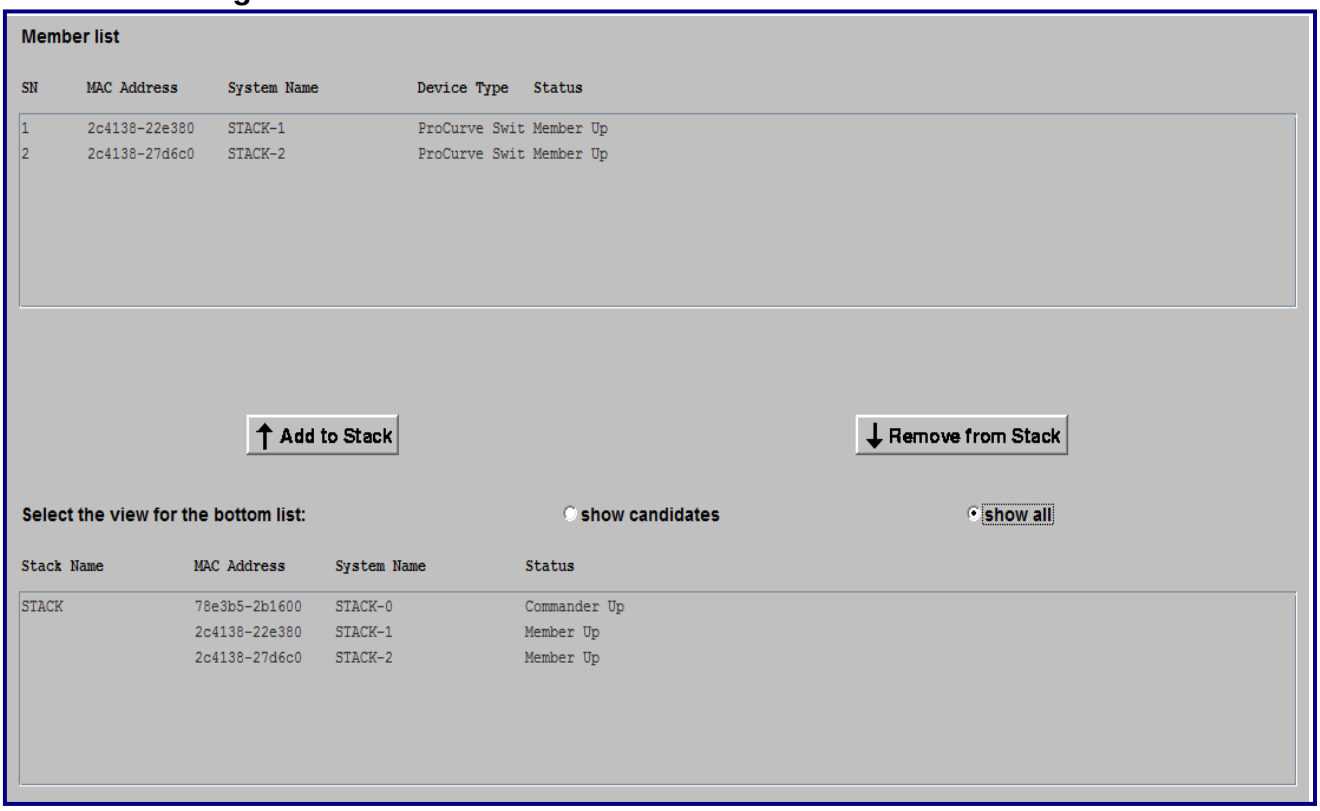
Within the D-Link GUI, users can toggle between the different switches in the stack by choosing a stack ID. When in a given switch, the top of the page displays port activity, and the role of the switch in a stack. If there is activity on a port, it is colored in green. Users can view port statistics by clicking on the active port.

The D-Link stack was tested for resiliency to verify configurations are automatically saved when the stack master is removed from the stack. One VLAN was created on the stack master, with the running configuration saved. A second VLAN was created, but the running configuration was not saved. The primary master was then removed from the stack, and the secondary master successfully took over its role. The second VLAN was preserved, because the configurations were automatically synchronized through the stack. There is no need to perform a copy of the running configuration. This ensures no configurations are lost when the primary master is removed from the stack.

HP

The 2910al series switches have SFP+ stacking ports that provide 10 Gbps throughput between each stack link. To create a stack with the HP switches, manual configuration of a commander is required before it is joined into the stack. By default, the 2910al series switches do not have the ability to automatically assign a switch as the stack master. The remaining switches in the stack are considered candidates; once they are configured into the stack they are members. Configuring the stack is done through the commander switch either through the GUI or CLI.

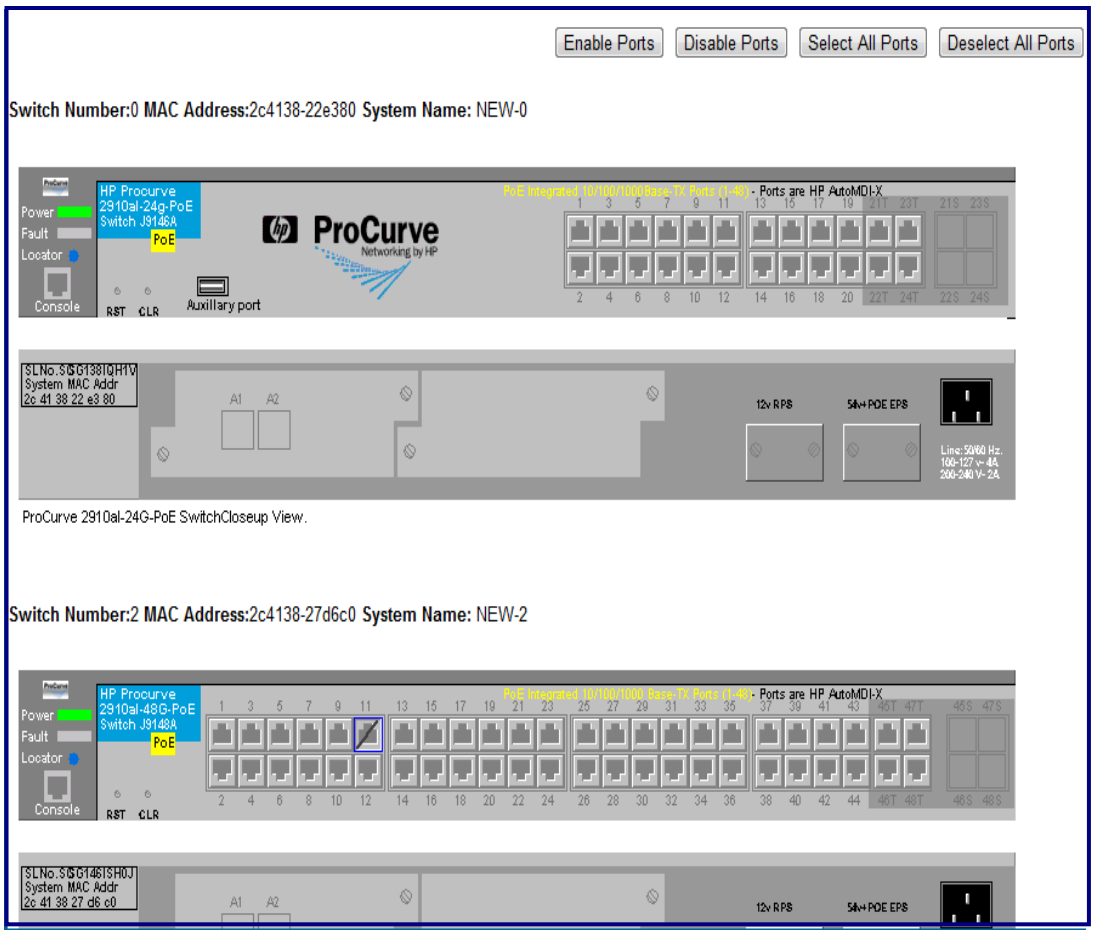
HP Stack Configuration



HP GUI allows users to add or remove switches from a stack.

Stacking configuration is done under the stack management page. Users can either add or remove switches from the stack through the stack commander. Switches that have not yet been assigned to a stack are considered candidates. Once they are assigned to a stack they are called members. The HP stack does not have a backup commander in case the primary commander experiences an outage.

HP Full Stack View



Full Stack View shows the switches that are part of the stack.

The Full View Stack screen shows switches that are part of the stack. Details that are displayed include the switch number, MAC address and system name. Ports can be easily disabled or enabled by clicking that option on the displayed port.

Indicators are not available on the front panel of the switch to provide role of the switch in the stack. Only by viewing the GUI or the CLI can the switch status be seen.

The HP stack does not have a secondary commander. When the primary commander was removed from the stack, the stack was no longer functional.

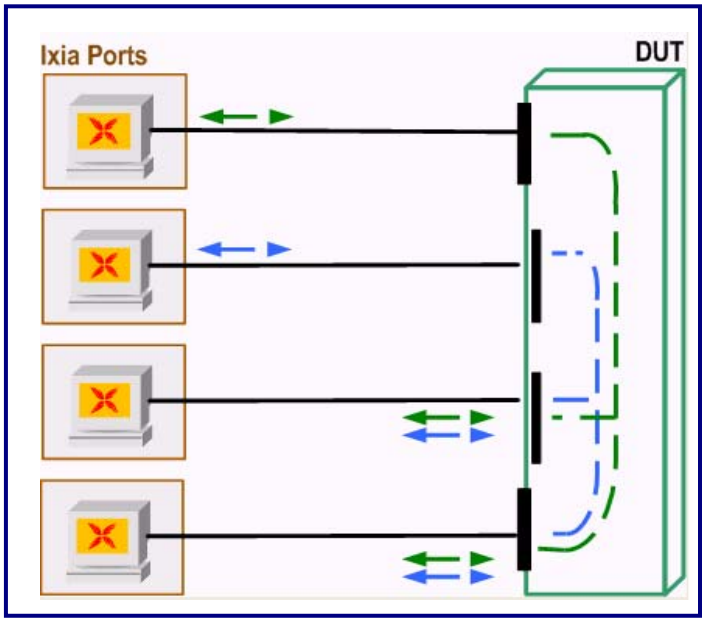
With an HP stack all ports, including stack ports need to be in the same VLAN in order for traffic to go from one switch to the other. HP switches function as a Cluster, rather than as a true stack, as noted previously. Normally in a stack, only the switch ports need to be added to a VLAN.

ACLs and QoS must also be configured on each switch individually, instead of once for the stack.

3.2 Stack Throughput

Throughput tests, based on RFC 2889 partial mesh, were run from ten ports on one switch to ten ports on another switch. This allows all ports of one switch to send traffic to all ports on the other switch. Traffic is bidirectional so both switches receive and send traffic on all ports. Frames of 64 to 1518 were run for thirty seconds on each frame size. The result is the throughput across the stack, with frame loss.

RFC 2889 Partially Meshed



Partially meshed throughput test sends bidirectional traffic from one switch to another

Cisco

The Cisco SG500X series switches support 10G SFP+ stack links; each of the switches in the stack were loaded with ten ports. Each switch sends 10 Gbps, the theoretical maximum.

During the partially meshed test, the Cisco switches achieved between 95.520% and 99.609% throughput. Frame loss was minimal and was due to untagged VLAN traffic being sent. Cisco switches do not use dedicated stack ports as the D-Link and Netgear switches use, rather they are equipped with 5G or 10G SFP+ uplinks for their stacking configuration. The SFP+ uplinks require additional fields in the frame header for the stacking protocol. However, if the switches are configured with tagged ports on the VLAN, the stack can achieve 100% throughput for 68, 128, 256, 1024 and 1280 frames. 1518 byte frames achieves 99.872% throughput across the stack.

With tagging enabled, the 802.1Q tag adds 4 bytes. Therefore 68 byte frames was tested instead of the standard 64 byte frames.

This test was also run on the SG500 series switches using 5G copper SFP uplinks and with 5 ports to max out the bandwidth. Results were similar to the SG500X series switches, with throughput ranging between 95.5% and 99.6%. When 802.1Q tagging was enabled, frame sizes 68 to 1280 were 100%. While the 1518 byte frame size had 99.9% on the SG500-52 stacked switch and throughput was 100% on the SG500-28.

Netgear

For Netgear, a GSM7252PS and two GSM7352S were configured in a ring stack. Units 2 and 3 were loaded with twelve ports each, with partially meshed traffic sent between them. Each switch sent and received 12 Gbps, for a total of 24 Gbps bidirectional traffic across each stack link. 100% throughput was recorded without any frame loss for all frames between 64 and 1518 bytes.

D-Link

The D-Link stack contained one DGS-3120-48TC and two DGS-3120-48PC switches in a duplex ring topology. The maximum throughput the D-Link stack was able to achieve was 13 Gbps, or 26 Gbps bidirectional throughput through each stack link without frame loss for all frames between 64-1518 bytes.

HP

For testing the HP stack, a 2910al-24G-PoE+, 2910al-48G and a 2910al-48G-PoE+ were configured in a ring topology. The maximum bandwidth achieved through the stack was 10 Gbps for frame sizes 64-1518 without any frame loss.

3.3 Stack Failover

When the switches are configured in a ring topology, what will the frame loss be when one stack link is removed? This test converts a stacked ring topology into a chain topology while traffic is being sent. When the switches are configured in a ring topology, each switch decides the best path for forwarding traffic. The sending switch chooses to send it from either the first or the second stack port.

Cisco

With traffic flowing between two stacked switches, a 10G stack link was disconnected. After verifying no frame loss, the stack link was plugged back in. When the second stack link was disconnected 33,083 frames were lost. When the link was reconnected there were no frames lost. There was no loss on the first link when it was disconnected since this port was not in the forwarding path. When the second link was removed frames were lost because it was in the forwarding state. Once the switch determined that the link was down, it changed the learning port to a forwarding port and traffic was forwarded once again.

Netgear

When link one was removed in the Netgear stack, there were 5,274,533 frames lost. When link one was reconnected there were 2,470 frames lost. Link two did not experience any frame loss when disconnecting and reconnecting the stack link.

D-Link

The D-Link switches experienced 590,657 lost frames when the first link was removed; no frames were lost when the stacking cable was plugged back in. When the second stack link was removed, there were 411,112 frames lost but no frames lost when the cable was reconnected. These results are different from the other vendors tested, since there is frame loss when both cables are removed at separate times. D-Link stack may be sending traffic out of both stack ports simultaneously to minimize bandwidth on each link.

HP

During the fast stack failover test, there were no frames lost when the first link was removed and reconnected. The link selected was not in a forwarding state for Spanning Tree (instead in a blocking state). When the second link was removed there were 457,911 frames lost. This reflects the time it takes for RSTP to move to a forwarding state. There was no frame loss when it was reconnected.

Stacking Summary Table

Features	Cisco	HP	Netgear	D-Link
Stacking Type	Ring/Chain	Cluster	Ring/Chain	Ring/Chain
Stacking LEDs	Y	N	Y	Y
Configure cross-stack QoS, ACL, Mirroring, LAGs	Y	N	Y	Y
Proper Auto Synchronization of VLAN config	Y	N	N	N
Backup Master option	Y	N	Y	Y
Automatically assigning Stack Master	Y	N	Y	Y
Correct operation when re-connecting previous primary to stack	Y	Y	Y	Reboots
Require separate Stack Module (additional cost)	N	N	Y	Y
Can mix 10/100 and Gigabit in the same stack	Y	Y	N	N
Stack throughput	100% (VLAN-tagged) /95%+ (untagged)	100%	100%	100%
Stack Failover	33,083 frames lost	457,911 frames lost	5,277,003 frames lost	1,001,769 frames lost

4.0 Energy Efficiency

Networks are currently being designed to consume the lowest amount of energy while maintaining optimal switch performance and resiliency. Energy saving features are built into switches to reduce energy consumption as well as to lower the operating cost. Having the ability to lower energy required while maintaining performance is vital, and was tested to determine which switches are energy efficient. Some of the switches tested here were designed with energy saving features while others were not. The Cisco SMB switches had the lowest energy consumption, since all of these models had the most energy efficient components.

Power Consumption *without* EEE

Configuration	Model	Power Usage		
		Without Energy Savings	With Energy Savings	Lowest Consumption (per category)
24-port 10/100	Cisco SF500-24	12.8	12.8	√
48-port 10/100	Cisco SF500-48P	44.3	44.3	√
24/28-port Gigabit	Cisco SG500X-24	34.3	33.7	
	Cisco SG500X-24P	54.7	53.9	
	Cisco SG500-28	22.6	22.1	√
	Cisco SG500-28P	34.7	34	
	HP 2910al-24G	60	N/A	
	HP 2910al-24G-PoE+	79.8	N/A	
48/52-port Gigabit	Cisco SG500X-48	58.7	57.2	
	Cisco SG500X-48P	76.8	75.4	
	Cisco SG500-52	46.5	45	√
	Cisco SG500-52P	62.9	61.6	
	D-Link DGS-3120-48PC	65.1	63.6	
	D-Link DGS-3120-48TC	56.6	56.2	
	HP 2910al-48G	79.8	N/A	
	HP 2910al-48G-PoE+	101.4	N/A	
	Netgear GSM7252PS	107.4	N/A	
	Netgear GSM7352S	90.2	N/A	

Power consumed by each switch with and without energy saving features enabled. N/A indicates that the switch does not offer energy saving features.

Cisco

The Cisco switches have four different forms of energy saving features: short-reach mode, energy-detect mode, disable port LEDs, and EEE (Energy Efficient Ethernet). With short reach, the transmitting power is reduced if the cable is less than 50 meters. Our testing used 4.26 meter cables, therefore transmit power was reduced. Energy-detect mode allows a port to go into an inactive state, reducing the power. Finally the EEE feature reduces power on ports by cutting transmitter power to any interface that is idle or during periods of bursty traffic.

During the full mesh throughput test, power consumption was recorded while energy features were first disabled and then enabled. With energy features disabled, the Cisco switches consumed between 12.8 watts and 76.8 watts. With energy features enabled, power consumption ranged between 12.8 watts and 75.4 watts. Overall the Cisco switches had the lowest power consumption when compared to switches in same categories.

Cisco Power Consumption *with* EEE

Cisco supports IEEE 802.az EEE. Transmitter power is cut whenever a port is either idle or if bursty traffic is observed. The tested D-Link, Netgear and HP switches evaluated do not support this feature.

In order to test the EEE power saving functionality, the first and last ports were connected to an Ixia XM12 traffic generator, while the remaining ports were connected in a snake fashion. For example, ports 2 and 3 are configured on the same VLAN, while port 3 is externally connected to port 4 with a crossover cable. All of the ports on the switch can see the same burst of traffic entering on the first port and exiting on the last port. This configuration was based on a Cisco /Intel whitepaper dated 2011.

The Ixia traffic generator was configured to simulate laptop/desktop users. The data pattern consisted of bursty traffic with 100% link utilization. Each burst of traffic consisted of 1,000 64-byte packets, with an inter-burst gap ranging from 96 nanoseconds to 110 milliseconds.

Power Savings with EEE enabled and a Bursty traffic profile

Cisco SG500-28P

IBG	Watts	Per port power saving (mW)
96ns	34.1	0
1.4ms	29.3	200
3ms	27.0	295.8
5.4ms	25.9	341.6
8ms	25.4	362.5
12.5ms	25.0	379.1
18ms	24.8	387.5
28ms	24.6	395.8
50ms	24.5	400
100ms	24.3	408.3
110ms	24.3	408.3
Best Case Savings: 9.8W		

Cisco SG500-28

IBG	Watts	Per port power saving (mW)
96ns	22.5	0
1.4ms	18.0	187.5
3ms	15.8	279.1
5.4ms	14.7	325.0
8ms	14.2	345.8
12.5ms	13.8	362.5
18ms	13.6	370.8
28ms	13.5	375.0
50ms	13.4	379.1
100ms	13.3	383.3
110ms	13.3	383.3
Best Case Savings: 9.2W		

Cisco SG500X-48P

IBG	Watts	Per port power saving (mW)
96**ns**	74.4	0
1.4ms	65.9	184.7
3ms	62.0	269.5
5.4ms	60.0	313.0
8ms	59.1	332.6
12.5ms	58.3	350.0
18ms	58.0	356.5
28ms	57.7	363.0
50ms	57.4	369.5
100ms	57.2	373.9
110ms	57.2	373.9
Best Case Savings: 17.2W		

Cisco SG500X-48

IBG	Watts	Per port power saving (mW)
96**ns**	58.0	0
1.4ms	49.2	191.3
3ms	45.0	282.6
5.4ms	43.0	326.0
8ms	42.1	345.6
12.5ms	41.5	358.6
18ms	41.1	367.3
28ms	40.9	371.7
50ms	40.7	376.0
100ms	40.5	380.4
110ms	40.4	382.6
Best Case Savings: 17.6W		

Cisco SG500-52P

IBG	Watts	Per port power saving (mW)
96**ns**	62.4	0
1.4ms	53.6	183.3
3ms	49.4	270.8
5.4ms	47.3	314.5
8ms	46.4	333.3
12.5ms	45.7	347.9
18ms	45.4	354.1
28ms	45.1	360.4
50ms	44.8	366.6
100ms	44.6	370.8
110ms	44.5	372.9
Best Case Savings: 17.9W		

Cisco SG500-52

IBG	Watts	Per port power saving (mW)
96**ns**	46.1	0
1.4ms	36.3	204.1
3ms	32	293.7
5.4ms	29.8	339.5
8ms	28.9	358.3
12.5ms	28.1	375
18ms	27.7	383.3
28ms	27.5	387.5
50ms	27.2	393.7
100ms	27.1	395.8
110ms	27.1	395.8
Best Case Savings: 19W		

Cisco SG500X-24P

IBG	Watts	Per port power saving (mW)
96**ns**	53.9	0
1.4ms	49.7	190.9
3ms	47.9	272.7
5.4ms	47.0	313.6
8ms	46.5	336.3
12.5ms	46.1	354.5
18ms	46.0	359
28ms	45.9	363.6
50ms	45.8	368.1
100ms	45.7	372.7
110ms	45.7	372.7
Best Case Savings: 8.2W		

Cisco SG500X-24

IBG	Watts	Per port power saving (mW)
96**ns**	35.8	0
1.4ms	31.3	204.5
3ms	29.3	295.4
5.4ms	28.3	340.9
8ms	27.8	363.6
12.5ms	27.4	381.8
18ms	27.2	390.9
28ms	27.1	395.4
50ms	27.0	400
100ms	26.9	404.5
110ms	26.9	404.5
Best Case Savings: 8.9W		

Cisco

With EEE enabled Cisco showed significant power savings. As the Interburst Gap increased and bandwidth utilization decreased, EEE became increasingly effective in taking advantage of idle times in the bursty traffic. We saw up to 19 watts saved on the SG500-52 switch, which is a 41% power savings from our baseline 100% utilization value.

Netgear

The tested Netgear switches did not have any energy saving features. Their power consumption ranged between 90.2 watts and 107.4 watts.

D-Link

The D-Link switches had some energy saving features. One feature shuts down the LEDs on the port. Another feature can detect whether a port is in use. If unused the port can be shut down. The length detection power saving feature, also known as short reach, enables lower transmitting power when shorter cables are used. With energy features disabled the switches consumed between 56.6 watts and 65.1 watts. With all of the features enabled, the switches consumed between 56.2 watts and 63.6 watts.

HP

These HP switches do not have any energy saving features. Their power consumption ranged from 60 watts to 101.4 watts. The HP switches support PoE+ which uses more power since it supplies additional watts for ports.

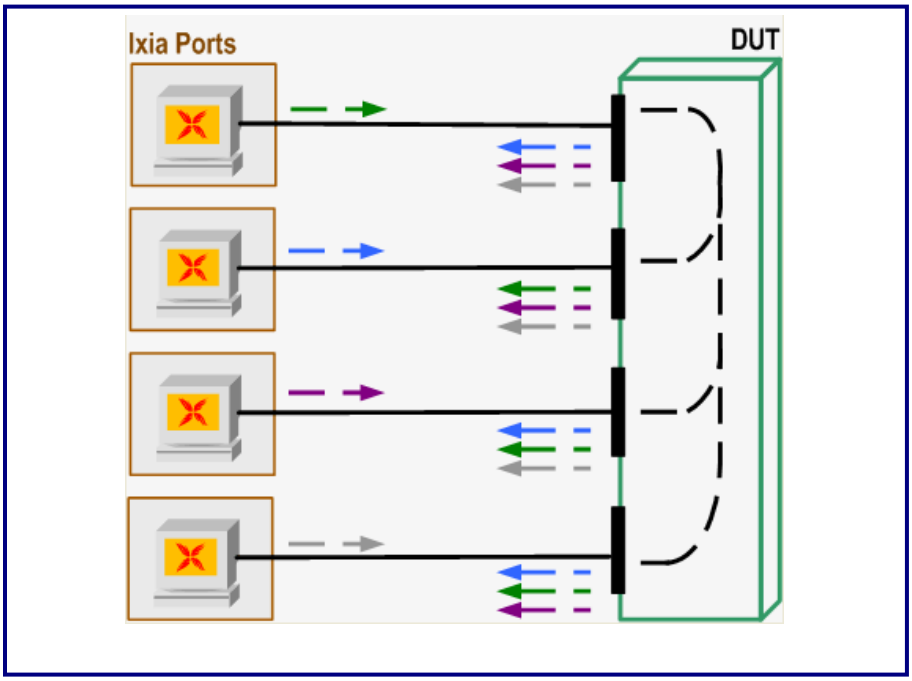
5.0 Performance Testing

Performance testing was conducted to verify that no frame loss occurred when sending and receiving traffic at line rate. Additionally, each switch was tested to verify its maximum MAC table size entries. While the switch was learning MAC addresses, the CPU utilization was recorded.

5.1 Full Mesh Throughput

Full mesh throughput testing verifies cross processor throughput while recording frame loss. Each port on the traffic generator sends traffic to the DUT, while receiving traffic from other ports, as shown below.
The switches were grouped into similar categories to ensure that like switches were tested and compared fairly.

RFC 2889 Full Mesh



RFC 2889 fully meshed test showing traffic flow between load generator and Device Under Test.

Throughput and Frame loss

Gig non-PoE		Ports	Throughput			Frame Loss		
			64	512	1518	64	512	1518
Cisco	SG500-28	28	151134	190906	195784	0	0	0
	SG500-52	52	290643	367128	376507	0	0	0
	SG500X-24	24	139508	176221	180724	0	0	0
	SG500X-48	48	279017	352443	361446	0	0	0
D-Link	DGS-3120-48TC	48	279017	352443	361446	0	0	0
HP	2910al-24G	24	139508	176221	180724	0	0	0
	2910al-48G	48	279017	352443	361446	0	0	0
Netgear	GSM7352S	48	279017	352443	361446	0	0	0
Gig PoE		**Ports**	**Throughput**			**Frame Loss**		
			64	**512**	**1518**	**64**	**512**	**1518**
Cisco	SG500-28P	28	151134	190906	195784	0	0	0
	SG500-52P	52	290643	367128	376507	0	0	0
	SG500X-24P	24	139508	176221	180724	0	0	0
	SG500X-48P	48	279017	352443	361446	0	0	0
D-Link	DGS-3120-48PC	48	279017	352443	361446	0	0	0
HP	2910al-24G-PoE	24	139508	176221	180724	0	0	0
	2910al-48G-PoE	48	279017	352443	361446	0	0	0
Netgear	GSM7252PS	48	279017	352443	361446	0	0	0
10/100 non-PoE		**Ports**	**Throughput**			**Frame Loss**		
			64	**512**	**1518**	**64**	**512**	**1518**
Cisco	SF500-24	24	13950	17622	18072	0	0	0
10/100 PoE		**Ports**	**Throughput**			**Frame Loss**		
			64	**512**	**1518**	**64**	**512**	**1518**
Cisco	SF500-48P	48	27901	35243	36144	0	0	0

All switches tested performed at line rate, with no frame loss.

Results from the fully mesh throughput test showed no frame loss for any switch tested. Each switch performed at line rate without any frame loss regardless of frame size. The Cisco SG-500-52P had the highest throughput of all the products in test.

5.2 MAC Table Size

The ability of a switch to learn MAC addresses was verified by recording the maximum MAC table size learned. CPU usage while the switch was learning its maximum MAC table size was also recorded.

The table size was verified by sending random MAC addresses to the switch and reviewing the table size in the GUI or CLI. CPU utilization was recorded while the switch was learning MAC addresses. CPU usage indicates switch processor efficiency while the MAC table is built.

The Cisco, HP, and D-Link switches stated 16,384 MAC address table and Netgear has a stated 8,192 MAC addresses. All of the switches built their MAC table size to the maximum except for the HP and Netgear switches which fell slightly short, regardless of learning rate. Exact numbers can be found in the table below.

Overall, the switches maintained low CPU utilization. Cisco had the lowest CPU utilization of 6%, while D-Link had the highest at 56%. This was due to D-Link switches allocation of 16% COU at idle. All of the other switches idle values, ranging from 0% to 8%. A high CPU utilization impacts affects other the resources performance of other CPU-intensive tasks, such as routing, management, and DoS prevention.

The GUI was used to verify the MAC table size in the Cisco, D-Link and Netgear switches. The HP switches uses a CLI was used to obtain the MAC table size.

MAC Address Table Sizes and CPU Utilization

Configuration	Model	Datasheet Value	Observed Table Size	Learning CPU Usage
Cisco	SF500-24	16,384	16,384	13%
	SF500-48P	16,384	16,384	20%
	SG500-28	16,384	16,384	13%
	SG500-28P	16,384	16,384	11%
	SG500-52	16,384	16,384	10%
	SG500-52P	16,384	16,384	26%
	SG500X-24	16,384	16,384	6%
	SG500X-24P	16,384	16,384	24%
	SG500X-48	16,384	16,384	10%
	SG500X-48P	16,384	16,384	12%
HP	2910al-24G	16,384	16,296	16%
	2910al-24G-PoE+	16,384	16,363	16%
	2910al-48G	16,384	16,363	8%
	2910al-48G-PoE+	16,384	16,356	11%
D-Link	DGS-3120-48PC	16,384	16,384	53%
	DGS-3120-48TC	16,384	16,384	56%
Netgear	GSM7252PS	8,192	8,190	20%
	GSM7352S	8,192	8,190	15%

All switches reached their stated maximum MAC table size except the HP and Netgear switches.

6.0 Resiliency and Security

Each switch was tested for resiliency and security with the Mu Studio Security tools. Various protocol mutations and DoS attacks were run on each switch to see if the GUI is affected and to measure CPU usage during the attack. Some test attacks could not be run because the switch correctly blocked the traffic. These are marked as N/A in the faults column in the table since the attack tool was unable to obtain responses during instrumentation. Operational indicates the DUT incurred no errors during test. All specific errors are noted as such.

6.1 Switch Management Responsiveness While Under Attack

The Web GUI on the switch was tested for performance while being subjected to protocol mutations and DoS attacks. This test demonstrates the effectiveness in mitigating attacks that are CPU intensive while maintaining manageability. If the GUI shows significant degradation or lack of responsiveness, it indicates that the DoS prevention feature is ineffective, and the switch functionality is being negatively impacted. Cisco was the only vendor in this test which passed all the tests with no failures.

Cisco SF500-48P

Cisco SF500-48P	CPU % Avg.	GUI	Faults	Number of Mutations or Duration of attack	Comments
ARP	5.40%	Operational	No Faults	465 mutations	ARP Messages
DHCP	6.20%	Operational	No Faults	11,843 mutations	INFORM Messages
ICMPv4	11.10%	Operational	No Faults	42,981 mutations	Echo Requests, Fragmented Echo Requests
ICMPv6	17.12%	Operational	No Faults	11,787 mutations	Destination Unreachable Messages, Echo Request Messages, Neighbor Advertisement Messages, Neighbor Solicitation Messages, Packet Too Big Messages, Parameter Problem Messages, Router Advertisement Messages
IPv4	10.21%	Operational	No Faults	31,129 mutations	IPv4 Datagrams, Fragmented Datagrams
IPv6	17.80%	Operational	No Faults	16,352 mutations	IPv6 Datagrams, IPv6 Fragments
TCP	10.06%	Operational	No Faults	3,417 mutations	Handshake Messages
UDP	5.72%	Operational	No Faults	6,411 mutations	IPv4 Datagrams
ICMP Flood	9.72%	Operational	N/A	5 minute duration	ICMPv4 Echo Requests
Large Ping Flood	9.30%	Operational	N/A	5 minute duration	ICMPv4 Echo Requests
TCP SYN FIN Flood	6.00%	Operational	N/A	5 minute duration	TCP SYN FIN Flood
TCP SYN Flood	15.83%	Operational	N/A	5 minute duration	TCP SYN Flood
IPv6 TCP Exploring	5.00%	Operational	N/A	5 minute duration	TCP Exploring Flood
IPv6 TCP SYN and FIN	4.50%	Operational	N/A	5 minute duration	TCP SYN and FIN Flood
IPv6 TCP SYN Flood	11.46%	Operational	N/A	5 minute duration	TCP SYN Flood
IPv6 UDP Flood	12.60%	Operational	N/A	5 minute duration	UDP Flood

Cisco SG500X-48

Cisco SG500X-48	CPU % Avg.	GUI	Faults	Number of Mutations or Duration of attack	Comments
ARP	2.57%	Operational	No Faults	465 mutations	ARP Messages
DHCP	6.85%	Operational	No Faults	11,843 mutations	INFORM Messages
ICMPv4	5.20%	Operational	No Faults	42,981 mutations	Echo Requests, Fragmented Echo Requests
ICMPv6	16.50%	Operational	No Faults	11,787 mutations	Destination Unreachable Messages, Echo Request Messages, Neighbor Advertisement Messages, Neighbor Solicitation Messages, Packet Too Big Messages, Parameter Problem Messages, Router Advertisement Messages
IPv4	6.42%	Operational	No Faults	31,129 mutations	IPv4 Datagrams, Fragmented Datagrams
IPv6	9.83%	Operational	No Faults	16,352 mutations	IPv6 Datagrams, IPv6 Fragments
TCP	6.66%	Operational	No Faults	3,417 mutations	Handshake Messages
UDP	4.88%	Operational	No Faults	6,411 mutations	IPv4 Datagrams
ICMP Flood	4.87%	Operational	N/A	5 minute duration	ICMPv4 Echo Requests
Large Ping Flood	6.30%	Operational	N/A	5 minute duration	ICMPv4 Echo Requests
TCP SYN FIN Flood	6.35%	Operational	N/A	5 minute duration	TCP SYN FIN Flood
TCP SYN Flood	8.90%	Operational	N/A	5 minute duration	TCP SYN Flood
IPv6 TCP Exploring	3.00%	Operational	N/A	5 minute duration	TCP Exploring Flood
IPv6 TCP SYN and FIN	3.00%	Operational	N/A	5 minute duration	TCP SYN and FIN Flood
IPv6 TCP SYN Flood	8.38%	Operational	N/A	5 minute duration	TCP SYN Flood
IPv6 UDP Flood	9.77%	Operational	N/A	5 minute duration	UDP Flood

Cisco SG500-52P

Cisco SG500-52P	CPU % Avg.	GUI	Faults	Number of Mutations or Duration of attack	Comments
ARP	4.27%	Operational	No Faults	465 mutations	ARP Messages
DHCP	7.07%	Operational	No Faults	11,843 mutations	INFORM Messages
ICMPv4	13.50%	Operational	No Faults	42,981 mutations	Echo Requests, Fragmented Echo Requests
ICMPv6	18.66%	Operational	No Faults	11,787 mutations	Destination Unreachable Messages, Echo Request Messages, Neighbor Advertisement Messages, Neighbor Solicitation Messages, Packet Too Big Messages, Parameter Problem Messages, Router Advertisement Messages
IPv4	14.66%	Operational	No Faults	31,129 mutations	IPv4 Datagrams, Fragmented Datagrams
IPv6	8.63%	Operational	No Faults	16,352 mutations	IPv6 Datagrams, IPv6 Fragments
TCP	11.70%	Operational	No Faults	3,417 mutations	Handshake Messages
UDP	7.50%	Operational	No Faults	6,411 mutations	IPv4 Datagrams
ICMP Flood	8.50%	Operational	N/A	5 minute duration	ICMPv4 Echo Requests
Large Ping Flood	11.27%	Operational	N/A	5 minute duration	ICMPv4 Echo Requests
TCP SYN FIN Flood	6.23%	Operational	N/A	5 minute duration	TCP SYN FIN Flood
TCP SYN Flood	7.20%	Operational	N/A	5 minute duration	TCP SYN Flood
IPv6 TCP Exploring	7.75%	Operational	N/A	5 minute duration	TCP Exploring Flood
IPv6 TCP SYN and FIN	7.22%	Operational	N/A	5 minute duration	TCP SYN and FIN Flood
IPv6 TCP SYN Flood	6.63%	Operational	N/A	5 minute duration	TCP SYN Flood
IPv6 UDP Flood	10.33%	Operational	N/A	5 minute duration	UDP Flood

Netgear GSM7252PS

Netgear GSM7252PS	CPU % Avg.	GUI	Faults	Number of Mutations or Duration of attack	Comments
ARP	Did not run*	N/A	N/A	465 mutations	ARP Messages
DHCP	4.35%	Operational	No Faults	11,843 mutations	INFORM Messages
ICMPv4	6.50%	Operational	No Faults	42,981 mutations	Echo Requests, Fragmented Echo Requests
ICMPv6	Inaccurate**	Partially Unavailable	75 High Level	11,787 mutations	Destination Unreachable Messages, Echo Request Messages, Neighbor Advertisement Messages, Neighbor Solicitation Messages, Packet Too Big Messages, Parameter Problem Messages, Router Advertisement Messages
IPv4	6.12%	Partially Unavailable	No Faults	31,129 mutations	IPv4 Datagrams, Fragmented Datagrams
IPv6	5.02%	Operational	No Faults	16,352 mutations	IPv6 Datagrams, IPv6 Fragments
TCP	N/A	Not Operational	N/A	3,417 mutations	Handshake Messages
UDP	4.29%	Operational	No Faults	6,411 mutations	IPv4 Datagrams
ICMP Flood	N/A	Not Operational	N/A	5 minute duration	ICMPv4 Echo Requests
Large Ping Flood	N/A	Not Operational	N/A	5 minute duration	ICMPv4 Echo Requests
TCP SYN FIN Flood	N/A	Not Operational	N/A	5 minute duration	TCP SYN FIN Flood
TCP SYN Flood	N/A	Not Operational	N/A	5 minute duration	TCP SYN Flood
IPv6 TCP Exploring	3.30%	Operational	N/A	5 minute duration	TCP Exploring Flood
IPv6 TCP SYN and FIN	3.63%	Operational	N/A	5 minute duration	TCP SYN and FIN Flood
IPv6 TCP SYN Flood	3.58%	Operational	N/A	5 minute duration	TCP SYN Flood
IPv6 UDP Flood	N/A	Not Operational	N/A	5 minute duration	UDP Flood

***Test could not be run because the switch did not accept the ARP messages.*
****The CPU usage output in the GUI did not display properly, causing inaccurate CPU readings.*

During the ICMPv6 protocol mutation test, the GUI was unavailable for a portion of the test. The IPv4 protocol mutation test also caused the GUI to become unavailable for a portion of the test. The GUI was unavailable for the entirety of the TCP protocol mutation test. The ICMP, large ping, TCP SYN FIN, TCP SYN, and IPv6 UDP floods caused the GUI to be inaccessible.

Netgear GSM7352S

Netgear GSM7352S	CPU % Avg.	GUI	Faults	Number of Mutations or Duration of attack	Comments
ARP	Did not run*	N/A	N/A	465 mutations	ARP Messages
DHCP	4.41%	Operational	No Faults	11,843 mutations	INFORM Messages
ICMPv4	4.99%	Operational	No Faults	42,981 mutations	Echo Requests, Fragmented Echo Requests
ICMPv6	Inaccurate**	Partially Unavailable	75 High Level	11,787 mutations	Destination Unreachable Messages, Echo Request Messages, Neighbor Advertisement Messages, Neighbor Solicitation Messages, Packet Too Big Messages, Parameter Problem Messages, Router Advertisement Messages
IPv4	6.13%	Partially Unavailable	No Faults	31,129 mutations	IPv4 Datagrams, Fragmented Datagrams
IPv6	7.46%	Operational	No Faults	16,352 mutations	IPv6 Datagrams, IPv6 Fragments
TCP	N/A	Not Operational	N/A	3,417 mutations	Handshake Messages
UDP	4.02%	Operational	No Faults	6,411 mutations	IPv4 Datagrams
ICMP Flood	N/A	Not Operational	N/A	5 minute duration	ICMPv4 Echo Requests
Large Ping Flood	N/A	Not Operational	N/A	5 minute duration	ICMPv4 Echo Requests
TCP SYN FIN Flood	N/A	Not Operational	N/A	5 minute duration	TCP SYN FIN Flood
TCP SYN Flood	N/A	Not Operational	N/A	5 minute duration	TCP SYN Flood
IPv6 TCP Exploring	3.93%	Operational	N/A	5 minute duration	TCP Exploring Flood
IPv6 TCP SYN and FIN	3.43%	Operational	N/A	5 minute duration	TCP SYN and FIN Flood
IPv6 TCP SYN Flood	3.40%	Operational	N/A	5 minute duration	TCP SYN Flood
IPv6 UDP Flood	N/A	Not Operational	N/A	5 minute duration	UDP Flood

**Test could not be run because the switch did not accept the ARP messages.*
***The CPU usage output in the GUI did not display properly, causing inaccurate CPU readings.*

During the ICMPv6 protocol mutation test, the GUI was unavailable for a portion of the test. The IPv4 protocol mutation test also caused the GUI to become unavailable for a portion of the test. The GUI was unavailable for the entirety of the TCP protocol mutation test. The ICMP, large ping, TCP SYN FIN, TCP SYN, and IPv6 UDP floods caused the GUI to be inaccessible.

The CPU displayed incorrectly in the GUI during the ICMPv6 test. During the test the 5 minute average was no longer shown and processes that were shown before the attack were no longer displayed. The CPU average would also show that the CPU was utilizing 0%.

D-Link (DGS-3120 series)

D-Link DGS-3120-48TC	CPU % Avg.	GUI	Faults	Number of Mutations or Duration of attack	Comments
ARP	16%	Operational	No Faults	465 mutations	ARP Messages
DHCP	16%	Operational	No Faults	11,843 mutations	INFORM Messages
ICMPv4	24% - When GUI available	Partially Available*	N/A	42,981 mutations	Echo Requests, Fragmented Echo Requests
ICMPv6	22%	Partially Available*	N/A	11,787 mutations	Destination Unreachable Messages, Echo Request Messages, Neighbor Advertisement Messages, Neighbor Solicitation Messages, Packet Too Big Messages, Parameter Problem Messages, Router Advertisement Messages
IPv4	23%	Partially Available*	N/A	31,129 mutations	IPv4 Datagrams, Fragmented Datagrams
IPv6	19%	Partially Available*	N/A	16,352 mutations	IPv6 Datagrams, IPv6 Fragments
TCP	22%	Operational	No Faults	3,417 mutations	Handshake Messages
UDP	17%	Operational	No Faults	6,411 mutations	IPv4 Datagrams
ICMP Flood	N/A	Not Operational	N/A	5 minute duration	ICMPv4 Echo Requests
Large Ping Flood	N/A	Not Operational	N/A	5 minute duration	ICMPv4 Echo Requests
TCP SYN FIN Flood	N/A	Not Operational*	N/A	5 minute duration	TCP SYN FIN Flood
TCP SYN Flood	N/A	Not Operational	N/A	5 minute duration	TCP SYN Flood
IPv6 TCP Exploring	92.00%	Some Slowness	N/A	5 minute duration	TCP Exploring Flood
IPv6 TCP SYN and FIN	90.00%	Some Slowness	N/A	5 minute duration	TCP SYN and FIN Flood
IPv6 TCP SYN Flood	N/A	Not Operational	N/A	5 minute duration	TCP SYN Flood
IPv6 UDP Flood	N/A	Not Operational	N/A	5 minute duration	UDP Flood

**Test could not be completed. Switch needed to be rebooted to access the GUI.*

During the ICMPv4, ICMPv6, IPv4 and IPv6 protocol mutation tests, the GUI was partially available. The CPU average ranged from 19% to 24%. The GUI was accessible for both of the IPv6 TCP exploring, and IPv6 TCP SYN and FIN, with the CPU reaching as high as 92% and the GUI displaying some slowness.

HP 2910al series

HP 2910al-24G	CPU % Avg.	GUI	Faults	Number of Mutations or Duration of attack	Comments
ARP	4.00%	Operational	No Faults	465 mutations	ARP Messages
DHCP	4.50%	Operational	No Faults	11,843 mutations	INFORM Messages
ICMPv4	7.00%	Operational	Unable to run	42,981 mutations	Echo Requests, Fragmented Echo Requests
ICMPv6	4.00%	Operational	2 High level	11,787 mutations	Destination Unreachable Messages, Echo Request Messages, Neighbor Advertisement Messages, Neighbor Solicitation Messages, Packet Too Big Messages, Parameter Problem Messages, Router Advertisement Messages
IPv4	4.00%	Operational	1 Low Level	31,129 mutations	IPv4 Datagrams, Fragmented Datagrams
IPv6	4.00%	Operational	No Faults	16,352 mutations	IPv6 Datagrams, IPv6 Fragments
TCP	4.50%	Operational	No Faults	3,417 mutations	Handshake Messages
UDP	4.00%	Operational	No Faults	6,411 mutations	IPv4 Datagrams
ICMP Flood	N/A	Not Operational	N/A	5 minute duration	ICMPv4 Echo Requests
Large Ping Flood	N/A	Not Operational	N/A	5 minute duration	ICMPv4 Echo Requests
TCP SYN FIN Flood	N/A	Not Operational	N/A	5 minute duration	TCP SYN FIN Flood
TCP SYN Flood	N/A	Not Operational	N/A	5 minute duration	TCP SYN Flood
IPv6 TCP Exploring	3.00%	Operational	N/A	5 minute duration	TCP Exploring Flood
IPv6 TCP SYN and FIN	N/A	Not Operational	N/A	5 minute duration	TCP SYN and FIN Flood
IPv6 TCP SYN Flood	4.00%	Partially Available	N/A	5 minute duration	TCP SYN Flood
IPv6 UDP Flood	N/A	Not Operational	N/A	5 minute duration	UDP Flood

The 2910al-24G remained operational during the protocol mutation tests. However during the DoS attacks, the GUI was only in operation for the IPv6 TCP exploring and IPv6 TCP SYN floods.

7.0 Ease-of-use

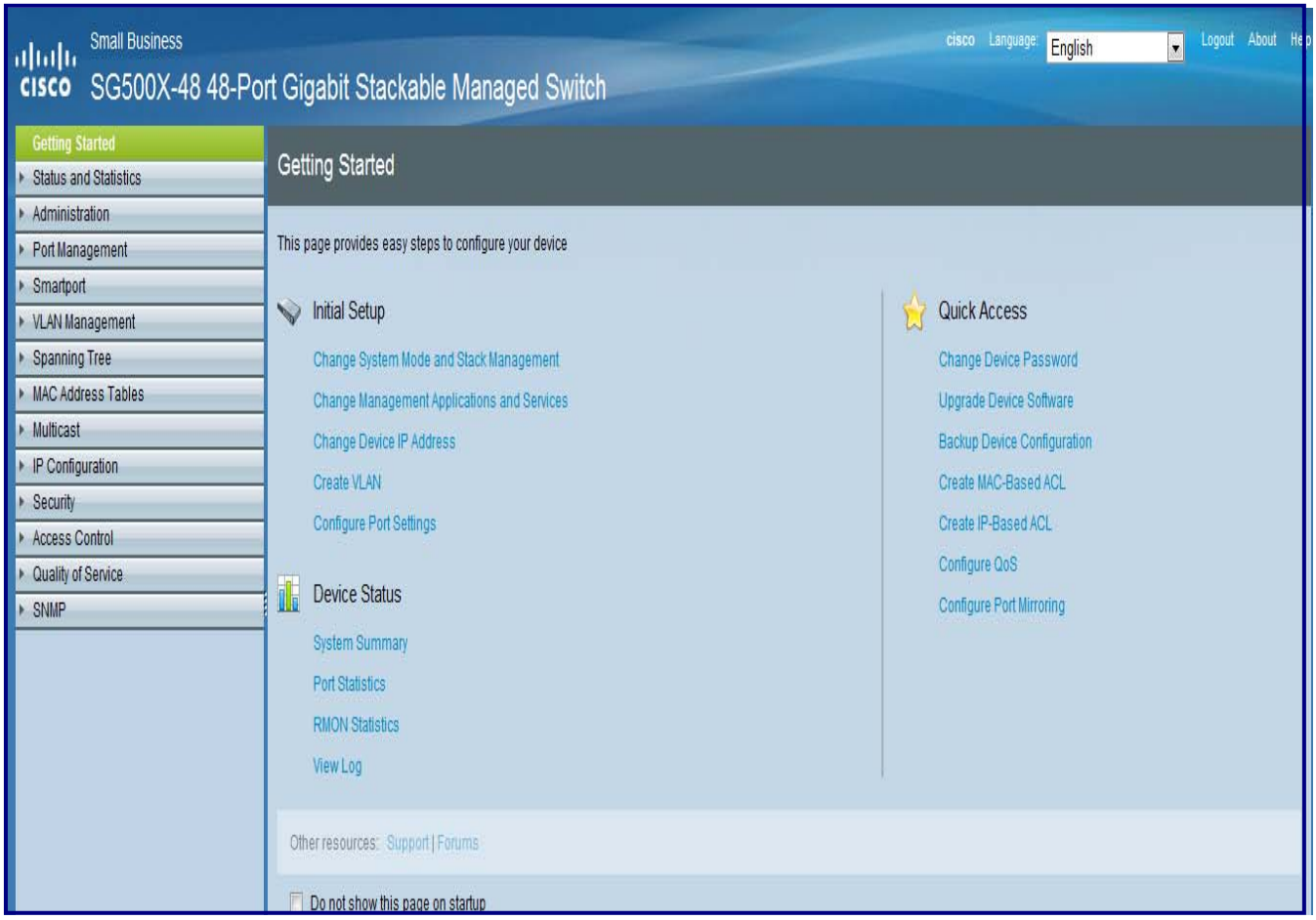
SMB switches should have a GUI to enable configuration changes easily. The GUI should be easy to read with properly named headings for simple navigation for configuration options.

All switches had a web GUI providing administration and monitoring features. The following section discusses the differences in web interfaces and the relative ease-of-use. Details about individual vendor utilization of the GUIs are also discussed.

7.1 Cisco (SF500, SG500, SG500X series)

The Cisco family of switches had a neat and organized web GUI. The menu bar contained all the features needed in easily identified categories for configuration. The following screen shot shows the Getting Started screen that appears after login.

Cisco Getting Started Screen



Cisco web GUI showing menu options for configuration settings.

All Cisco switches shared the same interface design. Cisco switches can also be configured in German, French, Spanish, Italian, Chinese, and English GUIs. Cisco also offers searchable tables across a stack for items such as MAC and Group addresses

The getting started page has quick configuration options that are required for first time use. New VLANs can be created or changing the IP address is easily handled from the getting started page. When all configurations are completed the getting started screen can be disabled. The status and statistics page will be displayed instead, showing system description, the firmware version, and other data.

The Cisco switch family supports IPv4, IPv6 and MAC based ACLs. Configurations for ACLs were easily found under the access control tab. To simplify configuration, Cisco implements a process flow e.g. ACE linked to ACL which is linked to the port binding. Also Policy Map linked to Class Map. The IP and MAC based ACLs were easily created by choosing the add option and naming an ACL rule. Applying specific rules to an ACL to deny, permit or shutdown, was done under the IPv4-based ACE, IPv6-based ACE or MAC-based ACE. ACL rules can be added, removed or updated from the GUI. ACL configurations could also be made in the CLI.

VLAN configurations were also available on the GUI under the VLAN management. VLANs and port assignments can be created by users with the VLAN option. The port to VLAN provides the ability to make a port tagged, untagged, excluded or forbidden.

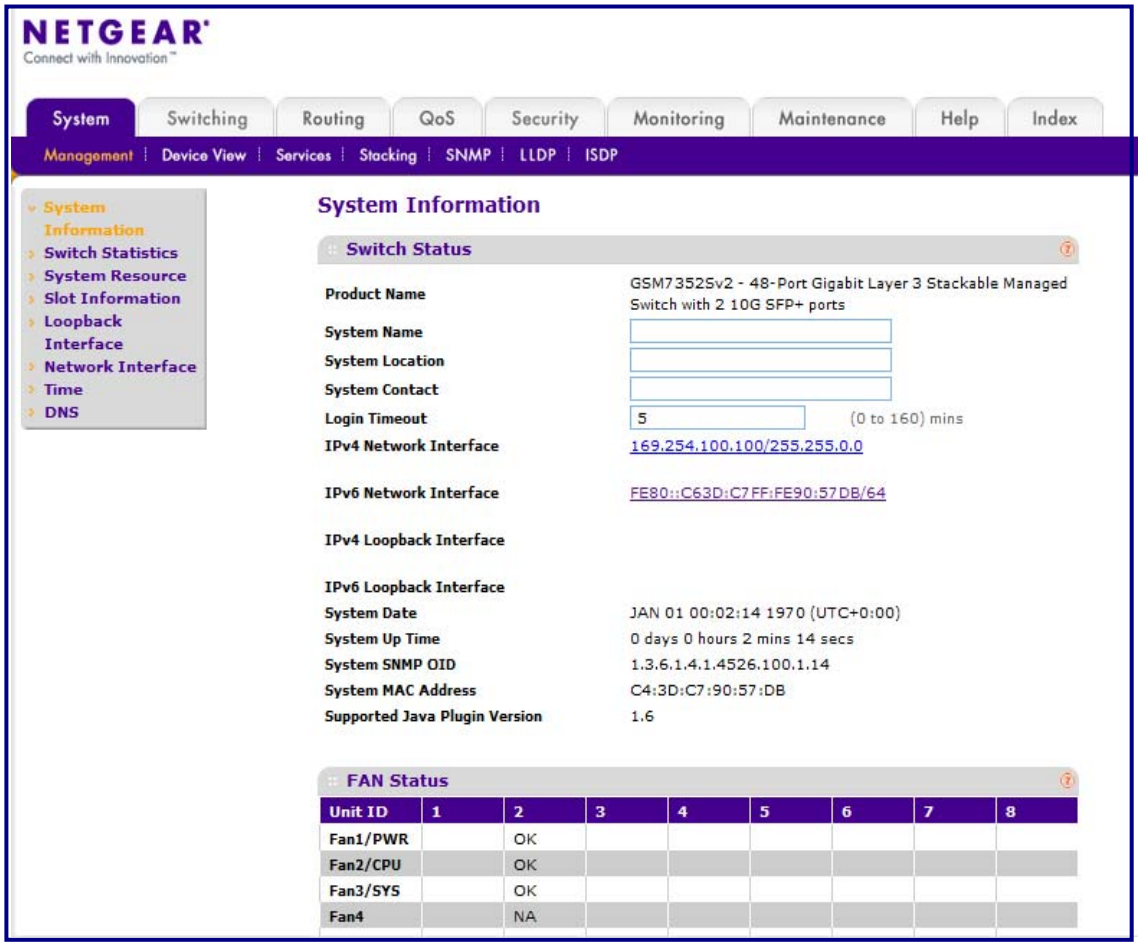
Another helpful menu option was the port VLAN membership page which provides a quick overview of which ports are assigned to VLANs. The Cisco CLI also has VLAN configuration options available.

Overall the Cisco GUI was easy to navigate, making it easy to find and perform configuration changes.

7.2 Netgear GSM7252PS, GSM7352S series

Both the GSM7252PS and GSM7352S series switches had the same GUI design. Navigating the GUI was simple, with easy to find configuration options. Features were properly labeled making it easy to find specific configuration areas.

Netgear System Information Page



Information page with basic information about the Netgear switch.

The ACL page was found easily under the security tab. The Netgear switches supported IPv4, IPv6 and MAC based ACLs. ACL rules were easily created by adding an ACL in the IPv4, IPv6 or MAC configuration page and then assigning permit or deny rules to IP or MAC addresses. ACL rules could also be made within the Netgear's CLI.

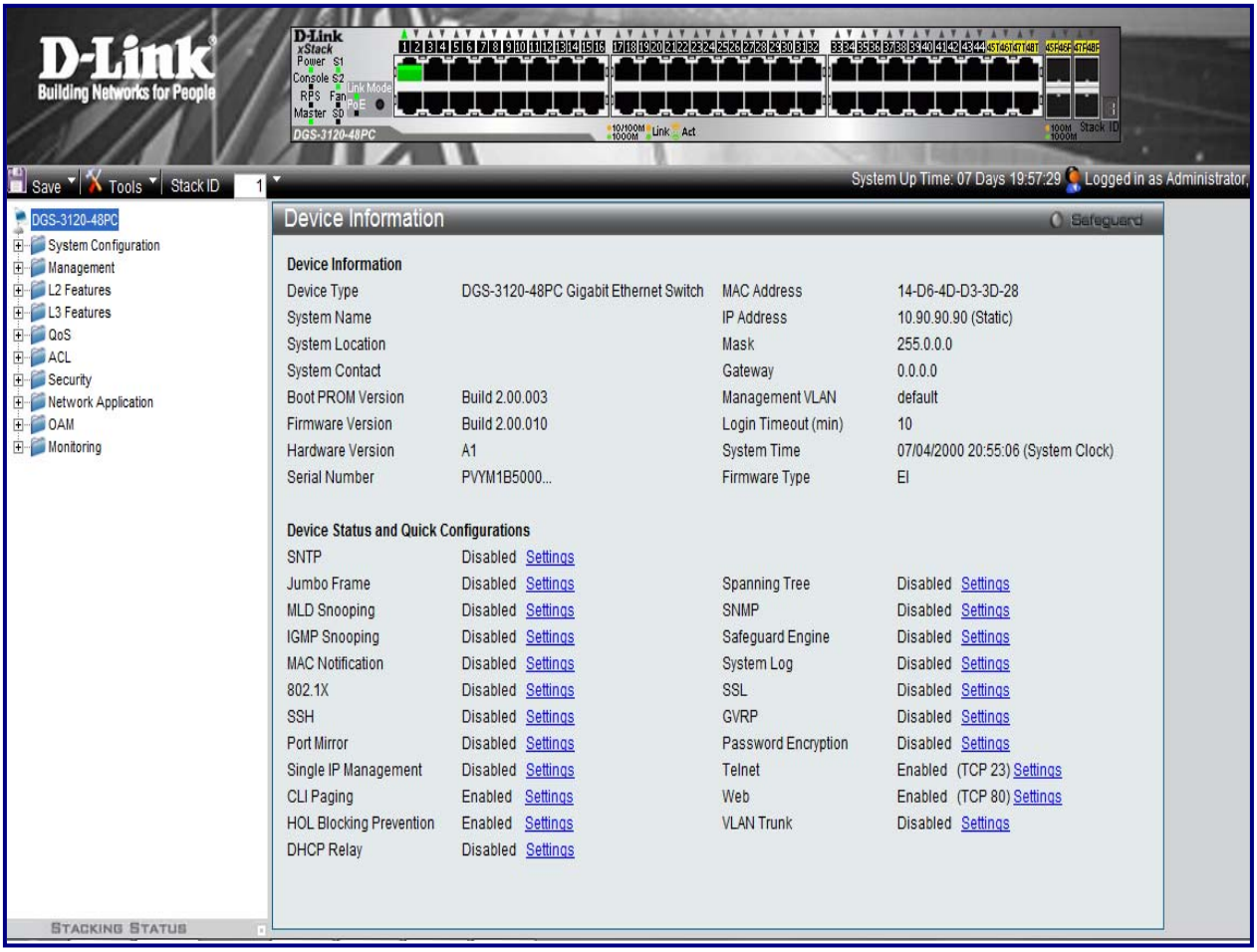
VLANs could also be configured in the Netgear's GUI under the switching tab. Users can assign ports to VLANs and make ports either tagged or untagged. Additionally the Netgear supports a VLAN status page, giving an overview of which ports are assigned to which VLANs. VLAN configurations could also be made with the Netgear's CLI.

Overall the layout of the GUI was very user friendly making it easy to find feature configurations.

7.3 D-Link DGS-3120-48PC, DGS-3120-48TC series

The two D-Link switches supported the same GUI design. The side menu bar was properly labeled making it easy to find specific configuration areas. The switch image at the top was a great added feature showing which ports were in use; however it only displays the stack master unit, which could be confusing. Ports that were in use can be clicked to provide additional port statistic information.

D-Link Device Information



The D-Link device information page gives a quick overview of system statistics.

ACL configuration options were easily found under the ACL menu in the side bar. D-Link supports an ACL configuration wizard which helps users create IPv4, IPv6 and MAC based ACLs. There is also a manual ACL configuration page. The D-Link switches also supported ACL configurations in the CLI.

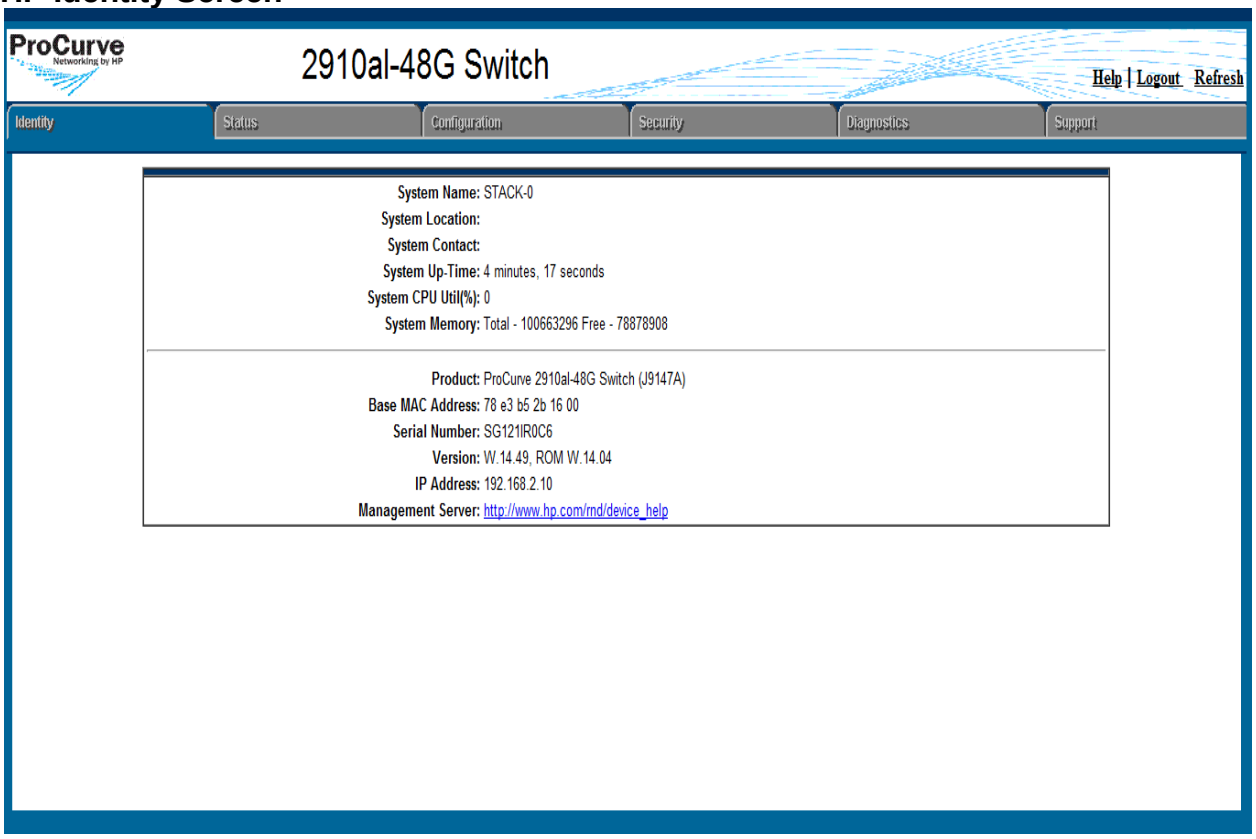
VLAN configurations were also possible in the GUI and easily found under the L2 features menu in the side bar. VLANs can be added, deleted or edited within the VLAN settings page. Users can assign ports to VLANs and can make ports tagged or untagged. The CLI could also be used to make VLAN configuration changes.

Overall the D-Link GUI was well designed with properly labeled options in the side menu bar, making it easy to find and configure specific criteria.

7.4 HP 2910al series

The 2910al series switches all have the same GUI design. The GUI had a tabbed format across the top of the page for configurations. The GUI was easy to navigate, but was not as feature rich as the other switches. Features were available for configuration in the CLI.

HP Identity Screen



The HP identity screen shows basic system information.

A security feature supported in the GUI was authorized addresses. Authorized addresses allows only specified IP addresses to access the switch GUI and to perform certain tasks. VLAN configuration is accessible using either the GUI or CLI.. VLANs could be added, removed or edited. Ports could be added to VLANs and configured for tagged or untagged traffic.

The HP GUI does not permit ACL configurations. These configurations are made through the CLI. On the HP switches ACL and QoS configuration had to be setup on each Switch independently. One ACL could not be configured on a single switch and then applied across all units in the stack. This is because it is functioning as a Cluster, and not a true stack.

Also, each HP switch has its own configuration for Spanning Tree, SNMP agent config, RMON Agent config. Again, this is due to the clustering. In a true stack, there is one configuration for the entire stack.

Ease-of-Use Summary

Features	Cisco	HP	NetGear	D-Link
Consistent UI design among models tested	Y	Y	Y	Y
Consistent UI across all switch categories	Y	N	N	N
GUI configuration of ACL	Y	N	Y	Y
Configure entire stack as single entity	Y	N	Y	Y
Multiple Local language configuration	Y	N	N	N
Searchable tables for MAC/Group addresses	Y	N	N	N
Configuration process flow in GUI	Y	N	N	N

8.0 Cost of Ownership Normalized Pricing

The cost of ownership, based on the price per gigabit and the cost of switch per PoE watt, was calculated by using published market prices, gigabit throughput, and the watts allocated for PoE usage. Calculating these values can determine the switch value based on the cost.

The switches were grouped in similar categories for a fair comparison. The chart below shows the 18 switches with their price per gigabit. Lower price per Gigabit is better.

8.1 Price per Gigabit Comparison

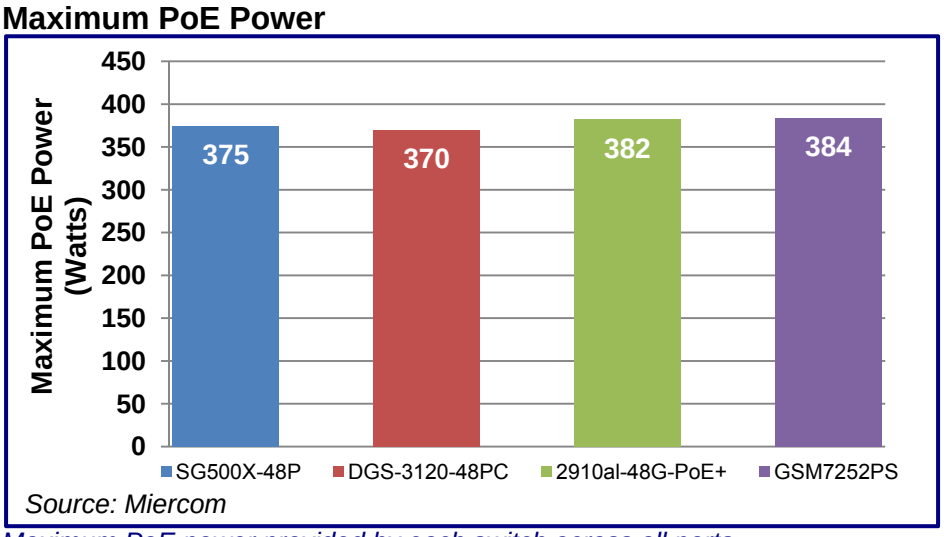
Gig non-PoE		Ports	Price per gigabit
Cisco	SG500-28	28	$3.77
	SG500-52	52	$3.70
	SG500X-24	24	$8.00
	SG500X-48	48	$6.09
D-Link	DGS-3120-48TC	48	$4.60
HP	2910al-24G	24	$11.44
	2910al-48G	48	$8.16
Netgear	GSM7352S	48	$8.94
Gig PoE		**Ports**	**Price per gigabit**
Cisco	SG500-28P	28	$5.10
	SG500-52P	52	$5.53
	SG500X-24P	24	$9.75
	SG500X-48P	48	$9.31
D-Link	DGS-3120-48PC	48	$7.27
HP	2910al-24G-PoE	24	$8.16
	2910al-48G-PoE	48	$10.49
Netgear	GSM7252PS	48	$9.36
10/100 non-PoE		**Ports**	**Price per gigabit**
Cisco	SF500-24	24	$22.87
10/100 PoE		**Ports**	**Price per gigabit**
Cisco	SF500-48P	48	$39.58

Cost of the switch per gigabit ranged from $3.70 to $39.58.
Cisco switches had the lowest price per gigabit.

8.2 Cost of Switch per PoE Watt

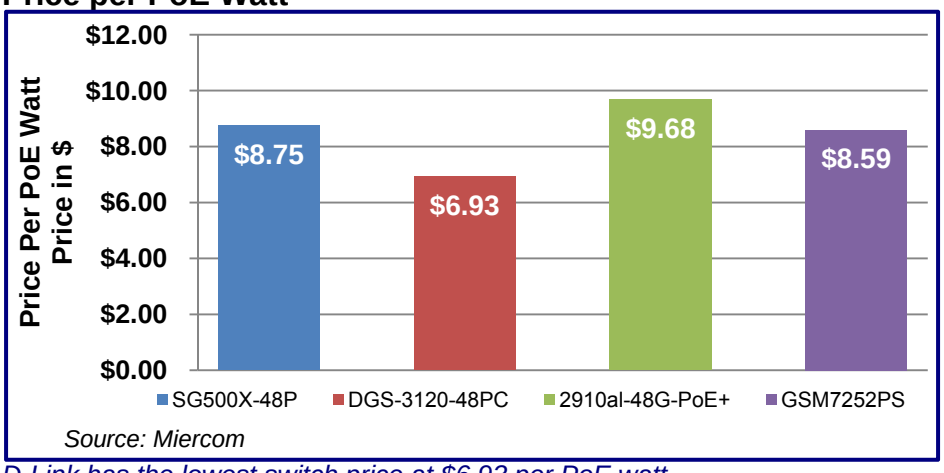
Cost of the switch per PoE watt was calculated using the PoE watt from data sheets and published market prices. To obtain a numerical value, the switch cost was divided by the PoE budget (number of watts allocated for PoE usage). A switch value increases when more PoE power can be utilized.

The switches with 48 and 52 ports were selected to be compared together. The 24 port switches were not included in the comparison since they do not output as many watts to their PoE ports as the 48- and 52-port switches.



Maximum PoE power provided by each switch across all ports.

Switch vendor datasheets, were used for maximum watts provided for PoE. This number was used to calculate the switch cost per PoE watts. This cost price does not include any power consumption costs.



D-Link has the lowest switch price at $6.93 per PoE watt

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9.0 Bottom Line

There were interesting data points collected during this stacking review. Overall, the Cisco switches had better or equal performance than the other switches. Cisco switches also exhibited the lowest power consumption per category. While the HP switches refer to a “stack” in their GUI, they actually perform as a cluster, instead of a true stack, requiring separate configuration of ACLs and QoS at each switch individually. In our resiliency tests, HP, Netgear and D-Link all experienced negative impact to switch functionality either from mutated packets or from DoS attacks. Cisco was the only vendor unaffected by any attacks directed at their switches.

Stacking Summary

	Cisco	HP	Netgear GSM7252PS	NetGear GSM7352S	D-Link
Capacity					
MAC table	16,384	16,384	8,192	8,192	16,384
Max VLANs	4,096	256	1,024	4,000	4,000
ACL rules	2,000	512	1,024	1,024	512
IP Routes	128	256	224	480	512
Throughput (line rate)					
Tagged VLAN	100%	100%	100%	100%	100%
Untagged VLAN	95%	100%	100%	100%	100%
Energy consumption					
Energy saving features	Y	N	N	N	Y
EEE	Y	N	N	N	N
Power consumption	Lowest	High	High	High	Moderate
GUI					
Consistent UI	Y	Y	Y	Y	Y
Configure entire stack as single entity	Y	N (cluster)	Y	Y	Y
Searchable tables	Y	N	N	N	N
Resiliency					
Efficient DoS Protection	Y	N	N	N	N
Efficient Handling of Protocol Mutations	Y	Y	N	N	N
Stacking					
Ring/chain	Y	N (cluster)	Y	Y	Y
Mix 10/100 and GE	Y	Y	N	N	N
Stack LED	Y	N	Y	Y	Y

10.0 Applicability of Test Results

The tests in this report are intended to be reproducible for customers who wish to recreate them with the appropriate test and measurement equipment. Current or prospective customers interested in repeating these results may contact reviews@miercom.com for details on the configurations applied to the Device Under Test and test tools used in this evaluation. Miercom recommends that customers conduct their own needs analysis review with us or any other proven network consultancy and test specifically for the expected environment for deploying new equipment.

This report was sponsored by Cisco Systems, Inc., and the data within obtained completely and independently as part of the Miercom Ethernet Switch Industry Assessment in which all vendors have equal opportunity to participate and contribute to the test methodology. All vendors involved in these tests were afforded opportunity to represent their products, and still have an opportunity to actively participate in the Industry Assessment and challenge any findings.