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Technical Network Equipment Qualification: Cubicle-class Switches

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Abstract

As part of the Testing Evaluation and Qualification Project, which was contracted by Organization 9336, this paper compares three cubicle-class switches from various vendors to assess how well they would perform in the unclassified networks at Sandia National Laboratories. The switches tested were the SMC TigerSwitch 6709L2, the Cisco Catalyst 2950G-12, and the Extreme Summit 5i. Each switch was evaluated by testing performance, functionality, interoperability, security, and total cost of ownership. The results of this report show the SMC TigerSwitch as being the best choice for cubicle use because of its high performance and very low cost. The Cisco Catalyst is also rated highly for cubicle use and in some cases may be preferred over the SMC TigerSwitch. The Extreme Summit 5i is not recommended for cubicle use due to its size and extremely loud fans but is a full featured, high performance switch that would work very well for access layer switching.

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1. Introduction

A "cubicle-class" switch is defined as being a switch that is on the "edge of the edge – the end user's cubicle" [1]. Ideally, this class of switch would be unnecessary and all end-user network connections would be provided by the access-layer switches. However, there are often occasions where more network connections are needed and there are not any more switch ports or copper/fiber connections available. Also, as Sandia moves towards an all-fiber infrastructure, cubicle-class switches will become increasingly important (since most PCs will have network cards that require copper). It is critical to understand the capabilities of these switches to determine how they will affect the overall end-to-end performance of Sandia's networks and what services these smaller switches are able to provide (i.e. management tools, monitoring tools, security, etc.).

The Design/Evaluation/Development Area (DEA) [2] is a document that describes the process that Sandia uses to evaluate new technologies for use in our network infrastructure. All parts of the DEA process were applied to this project excluding the deployment model. A test plan was created based on Sandia's current network functions (in accordance with the DEA) to determine if the performance and capabilities of each switch are able to be successfully used in Sandia's environment. Four cubicle-class switches were initially selected to be evaluated from different vendors. During testing, one switch (Foundry 10GC2F) was eliminated because it is no longer available for purchase. That left three switches: the SMC TigerSwitch 6709L2, the Cisco Catalyst 2950G-12, and the Extreme Summit 5i.

This paper presents the results for each switch and is organized into four sections. The first section describes both the equipment used for testing and the units under test (UUT). The second section presents the test plan that that was applied to each switch. The third section provides the results gathered from testing. The final section states our conclusion and the switch we recommend for field testing. Appendix A presents the test results and Appendix B shows performance results for the Forward Pressure test.

2. Units Under Test and Testing Equipment

This section presents all the equipment that was used for the testing process. It describes the basic switch description, firmware version, etc. The reader may want to skip ahead to the next section if not interested in the description of the switches or testers.

2.1. Cisco Catalyst 2950G-12

The Cisco Catalyst 2950G-12 has twelve 10/100BASE-T ports and two Gigabit Interface Converter (GBIC) ports. The 2950G also comes in a 24 and 48 port version. The dimensions of the switch are 1.72 x 17.5 x 9.52 inches (H x W x D). It can easily sit on a desk and makes about the same amount of noise as a PC. For more information on operating environment, noise, etc. of the 2950G-12, refer to the data sheet which can be found at [3].

The switch tested was running Cisco Internetworking Operation System (IOS) Software (C2950-I6Q4L2-M), Version 12.1(12c) EA1, Release Software (fc1). It contained a Cisco WS-C2950G-12-EI (RC32300) processor (revision F0).

2.2. Extreme Summit 5i

The Extreme Summit 5i has twelve 100/1000BASE-T ports and four GBIC ports. Instead of the twelve 100/1000BASE-T ports, the Summit 5i also can come with twelve 1000BASE-SX or 1000BASE-LX ports. The dimensions of the switch are 3.5 x 17.25 x 19 inches (H x W x D). This switch is meant to be rack mounted (i.e. would not fit well on a desk) and is much louder than a standard PC. For more information on the Summit 5i, the reader may go to [4].

The switch tested was running Extremeware Version 6.2.2 (build 68) by Release_master 01/15/02 16:58 and BootROM version 7.6.

2.3 SMC TigerSwitch 10/100 (SMC6709L2)

The SMC TigerSwitch has eight 10/100BASE-T and one 10/100/1000BASE-T port. It has two expansion slots: one that supports 100BASE-FX SMF/MMF and the other that supports 1000BASE-T/SX/LX. The TigerSwitch by far is the most compact switch tested. It takes up very little space on a desk and is extremely quiet. For more information on the SMC TigerSwitch, the data sheet can be found at [5].

The switch tested was running firmware version 03.10, hardware version 03.00 and flash version 26.00.

2.4 Spirent Smartbits 6000B

The Spirent Smartbits 6000B is a network performance analysis system that was used to test the three switches on various performance benchmarks. It can support up to 12 different modules. The specific modules we used are the LAN-3311A which supports data rates of 1000 Mbits/sec. on two GBIC-based ports and the LAN-3100A which supports 10/100BASE-TX Ethernet on 8 ports.

The Spirent chassis was version 2.00.010. The LAN-3311A was using firmware version 3.50.054 and the LAN-3100A was using firmware version 1.05.002. The

Spirent tester comes with multiple applications that test different performance aspects. The ones used in this test were SmartApplications and Advanced Switch Test II (ASTII). SmartApplications was version 2.50, its API version was 1.00-28, and its library version was 3.12-115. ASTII was version 2.10.015, its API version was 2.10.015, and its library version was 3.12-115,

3. Test Plan

The test plan consisted of six major sections: Functionality and Interoperability, Management and Diagnostics, Similarity of Management Interface to Cisco, Performance, Security and Access Control, and Total Cost of Ownership. Each section has multiple items that were tested. This test plan was developed in collaboration with the Telecommunications Operation Department (Org. 9334) and tries to capture all the functions currently used in the network and functions that will most likely be implemented in the future. An emphasis was placed on testing how well a switch was able to implement a standard, rather than a proprietary protocol that is unable to communicate with switches from different vendors. The following subsections will list each test performed and give a brief explanation. The test plan was written to include switches larger than cubicle-class switches, so certain tests will not apply for the units under test (UUT) in this paper (e.g. testing if the switch has blades that are "hot swappable").

Each test was set up differently depending on what feature was being tested. Figure 1 shows the setup used for performance testing. Each unit was connected to a Lantronix terminal server through its console port. This allowed the testers to have remote access to each switch. The Smartbits tester was connected to the network and also accessible remotely. Connections were made between the Smartbits and the UUT as shown below. After the test was finished, the connection to the UUT from the Smartbits was removed and then the next UUT was connected to the Smartbits tester.

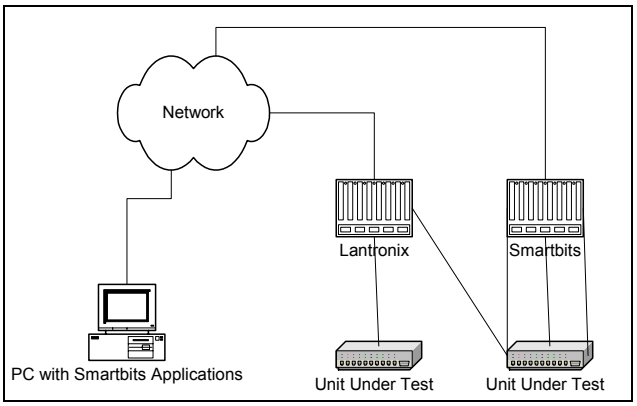

Figure 1: Performance Testing Setup

For non-performance testing, each test setup was designed specifically to illustrate if the feature under test worked correctly. Figure 2 shows an example of the setup used for testing the spanning tree protocol that we named the Olsberg Triangle. This was named after Ron Olsberg (9336) who came up with the setup. Two existing switches (an Extreme and a Cisco) were hooked up together with spanning tree active. Each UUT was connected to both the Extreme and the Cisco switches so that each switch had two connections to the other two switches. Each switch was monitored to determine if the spanning tree protocol was working. If all the switches were implementing the spanning tree protocol correctly, any connections that created a loop would be disabled but the tester would be able to ping from any one switch to any other switch. Spanning tree was also tested by disconnecting the active connection for each side of the triangle and verifying that an inactive connection became active.

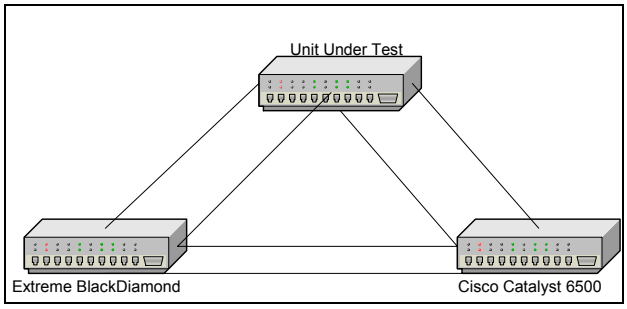

Figure 2: The Olsberg Triangle

3.1. Functionality and Interoperability

The following tests attempt to clarify the abilities of the switch and how well it is able to communicate with another switch using standard protocols.

- **Port Capacity:** To determine the number of ports on each UUT, the type of port (i.e. copper, fiber, LX, SX, etc), and its respective speed (i.e. 10/100/1000 Mbits/sec).
- **Monolithic Switch Module Availability:** To determine if the UUT has modular ports used for the uplink.
- **VLAN Support:** To determine if the UUT can create and support multiple VLANs.
- **802.1d:** 802.1d is an IEEE standard for Ethernet Bridging with the spanning tree protocol (STP). This test is to determine its ability to implement 802.1d and communicate with other switch vendors.
- **PVST+:** PVST+ (Per VLAN Spanning Tree) is a Cisco proprietary protocol that expands on 802.1Q (IEEE standard for VLAN bridges). This test is to determine whether other UUT are

able to communicate with the Cisco switch using spanning tree.

- **PortFast (or Equivalent):** PortFast is a Spanning Tree mechanism that reduces the amount of time it takes a host to connect to a switch. It does this by skipping the blocking, listening, and learning states. This should only be used when connecting a switch directly to the host or loops can be formed. This test is to determine if the UUT supports PortFast or an equivalent.
- **802.1Q:** 802.1Q (also know as Tagged VLANs) is the IEEE standard for VLAN bridges. This test is to determine if 802.1Q is implemented correctly on each UUT.
- **802.3ad:** 802.3ad is an IEEE standard for provider bridges (more commonly known as link aggregation). This test determines if the UUT is capable of implement 802.3ad.

3.2. Management and Diagnostics

The following tests try to determine what management and diagnostic tools are available for each UUT.

- **Command Line Interface (CLI):** To determine whether the UUT supports a CLI or only uses menu-based administration.
- **Telnet in:** To determine if the UUT allows users to *telnet* to the switch.
- **Telnet out:** To determine if the UUT is able to execute the *telnet* command.
- **Ping out:** To determine if the UUT supports the *ping* command.
- **Web/http(s) support:** To determine if the UUT is configurable or viewable through a Web interface.
- **Secure Shell (SSH) 1/1.5/2 support:** To determine if the UUT supports a version of SSH. This item could also be placed under security since it replaces the *telnet* command which is not secure since it sends out unencrypted passwords on the network.
- **Proprietary Switch Management Software:** To determine if the UUT can be configured with proprietary management software.
- **Switch Stacking:** Switch stacking enables multiple switches to be linked together and act as one switch. This test determines if switch stacking is available on the UUT.
- **Simple Network Management Protocol (SNMP) read/write:** To determine if the UUT is capable to be viewed and/or configured over the network using SNMP.
- **Hot Swappable:** Hot swapping means that the switch is able to have a blade/module removed and another inserted and still function normally without needing to shutdown/reboot the switch. This test determines if the UUT supports hot swapping.
- **Redundant Modules:** Redundant modules allow a switch to have a failure on one module and immediately fail over to another module. This test is to determine if the UUT has a redundant module and that it works properly.
- **Port Mirroring:** Port mirroring (which is also called wire tapping) will mirror traffic specified on one port to other ports. This function is used for monitoring purposes. This test determines if the UUT supports port mirroring.
- **File Upload/Download:** This test determines what file upload/download protocols the UUT supports.

3.3. Similarity of Management Interface to Cisco

Sandia National Laboratories networks are made up mostly of Cisco products. The following tests try to determine how similar the UUT's interface is compared with Cisco. These tests are important since our production staff is familiar with Cisco products and it potentially could take a lot of time to learn another dramatically different CLI.

- **CLI Look and Feel:** To determine if the UUT has a look and feel similar to Cisco. If not similar, how easy is it to understand and learn?
- **Vty Password:** To determine if the UUT has vty password support similar to Cisco, such that the user is only prompted for a password.
- **Vty Enable Password:** To determine if the UUT supports enable passwords to gain access to privileged commands in a similar manner as Cisco.

3.4. Performance

An important measure of any switch is how well it will be able to perform in the network. The following tests all use the Spirent Smartbits tester to gather performance measurements. The first four tests listed below are tests found in the SmartApplication suite and the last four tests belong to the ASTII suite.

- **Throughput:** Tests the fastest rate that the UUT can forward frames without an error.
- **Latency:** The time it takes starting when the last bit of the frame reaches the input port and ending when first bit of the frame reaches the output port. There are two types of latency

reported by the SmartApplication suite: *cut-through* and *store and forward*. The SmartApplication suite defines *cut-through* latency as "the difference between the time that the end of the first bit of a transmitted frame reaches the [UUT's] input port (Transmit Timestamp) and the time the first bit of the same frame is seen on the [UUT's] output port (Receive Timestamp)." It defines *store and forward* latency as "the difference between the time that the end of the *last* bit of a transmitted frame reaches the [UUT's] input port (Transmit Timestamp) and the time that the end of the *first* bit of the same frame leaves the [UUT's] output port (Receive Timestamp)."

- **Frame Loss Rate:** The percentage of frames lost by the UUT that should have been forwarded but were not due to lack of resources.
- **Back-to-Back:** How well the UUT can handle fixed length frames that are sent with the minimum legal time between each frame over a short period of time.
- **Forward Pressure:** The Forward Pressure test simulates congestion by sending packets with a smaller than legal interframe gap between each packet.
- **Broadcast Forwarding:** Test the ability of the UUT to forward broadcast packets out multiple ports.
- **Error Filtering:** Simulates erroneous packets to determine if the UUT will detect them. The errors selected to test for this experiment were CRC errors, oversized frames, and undersized frames.
- **Address Learning:** This test determines the learning rate of the UUT. The learning rate is the maximum rate that the UUT is able to learn new MAC addresses without flooding or dropping frames.

3.5. Security Access Control

The following tests are to determine what security access control functions are available for the UUT.

- **TACACS+ (Terminal Access Controller Access Control System):** TACACS+ was developed by Cisco and is a method of information exchange between a device that provides network access and a device that contains authentication information for users of that device. This test determines if the UUT supports TACACS+.
- **RADIUS (Remote Authentication Dial In User Service):** The RADIUS protocol is a method of sharing authentication, authorization, and configuration information between a shared authentication server and a network access server. This test determines if the UUT supports RADIUS.
- **User Password:** To determine if the UUT supports user passwords (as opposed to administrative login passwords).
- **User Authentication Levels:** To determine if the UUT can have different authorization levels for different users.

3.6. Total Cost of Ownership

Total cost of ownership can be calculated many different ways. This paper presents total cost of ownership by listing off all of the different costs (e.g. list price, technical support costs, etc.). It is left to the reader to apply any total cost of ownership equations that take in multiple years of use. The following tests are to determine how much it costs to own and deploy the UUT in Sandia's network (which is different than how much it costs to simply purchasing the switch).

- **List Price:** Determine the current list price to purchase the UUT.
- **Cost per Port:** Determine the cost per port for the UUT. This equation is not purely the list price divided by the number of ports. A standard configuration was selected (i.e. using all the standard ports plus one uplink) and used to determine cost per port.
- **Technical Support:** Determine how much technical support costs and what hours it is available for the UUT.
- **Reliability:** Determine the meantime until failure for the UUT.
- **Availability:** This can be calculated by dividing the Mean Time To Failure by the Mean Time To Failure plus the Mean Time To Repair (we will assume the MMTR is a half hour in this paper) or: $\frac{MMTF}{MMTF + MMTR}$
- **Warranty Period:** Determine the warranty period for the UUT.

4. Test Results

Results for each of the major test categories will be discussed in the following sub-sections. In most cases, the three cubicle-class switches support the same features and have similar performance results. The following paragraphs will focus on how the switches differ in each of the major categories. The complete set of results can be found in Appendix A.

4.1. Functionality and Interoperability

Each switch is similar in functionality. The SMC has the lowest port count with 8 10/100BASE-T ports while the Cisco has 12 10/100BASE-T ports and the Extreme has 12 100/1000BASE-T ports. Cisco is the only switch that supports PortFast. All switches passed interoperability tests by either supporting the feature tested or by being compatible with the feature.

4.2. Management and Diagnostics

Again, each switch had many similar features. The Cisco 2950G was the only unit that supports switch stacking. The only feature it did not support was SSH. The Extreme Summit 5i was the only UUT that supported SSH (version 2). It does not support switch stacking and it does not support any management software (though it does support web-based management). The Extreme Summit 5i supports SCP, BOOTP, and TFTP while the other switches only support TFTP. The SMC TigerSwitch does not support "telnet out", SSH, or switch stacking.

4.3. Similarity of Management Interface to Cisco

Obviously, the Cisco 2950G is 100% similar to Cisco because it is a Cisco product. The Extreme Summit 5i has a CLI that works similarly to Cisco. Instead of using a "?" to check for available commands, the Extreme requires a TAB. There is no enable password. Some commands are not named the same as found in Cisco's CLI, but it should only take a few hours for someone who has networking experience to be able to learn and execute all of the basic functions. The SMC TigerSwitch has a menu based management interface. It is very easy to use for even a novice. The SMC also has a CLI, but it is very clunky and nothing at all like Cisco's CLI. Another annoyance with the SMC interface is that is has a two minute inactivity timeout that can be set higher, but will not be saved when the switch is rebooted.

4.4. Performance

All switches performed extremely well. For throughput, each switch passed the throughput test 100%. The SMC was the surprising winner in the latency test (when comparing latency of the 10/100 or 100/1000 BASE-T ports). Its cut-through latency was 124.5 microseconds and its store-and-forward latency was 3 microseconds. Extreme took second place with 196.4/74.9 microseconds (respectively) and Cisco in last with 284.6/183.1 microseconds. All switches had 0% frame loss and passed the back-to-back test at 100%. All three also had perfect scores in broadcast filtering, error filtering, and address learning. Appendix B shows each switch's forward pressure test results. The Extreme performed the best under the congested environment. Cisco performed perfectly on its 10/100 ports but it would not communicate through its GBIC ports for this particular test. The SMC suffered a slight amount of loss on one connection bringing its total loss to about 20%. This is not too bad considering the tester is sending frames with a smaller inter-frame gap than is legal.

4.5. Security Access Control

Both the Cisco and the Extreme switch are able to perform TACACS+ and RADIUS. They both support user passwords and multiple authentication levels. The SMC TigerSwitch did not do as well. It does not support TACACS+, RADIUS, or user password and authentication levels. It only has administrative passwords and authentication.

4.6. Total Cost of Ownership

While the SMC unit may not have faired well in the last section, it really shines in this one. By far, it has the cheapest list price at $350.88 ($38.99 per port). It has free 24/7 tech support for the life of the product, a meantime to failure of 70,080 hours (99.99929% availability) and a 3 year hardware/software warranty. The 2950G has a list price of $2,295 ($176.54 per port). 8x5xNBD (next business day) tech support costs $185/year. Its meantime to failure is predicted to be 318,440 hours (99.99984% availability) and a limited lifetime hardware/software warranty. The Summit 5i has a list price of $10,995 ($845.76 per port). It has NBD tech support for $950 a year. The meantime to failure is a minimum of 50,000 hours (99.999% availability) and has a 1 year warranty on hardware/software.

5. Conclusion

All three switches are of excellent quality and would perform well in Sandia's environment. But since this paper is focusing on switches that would be ideal for use in a cubicle, the Extreme Summit 5i is not recommended. While it performs well and has features the other two switches do not have (e.g. SSH version 2), it is too large and too noisy to be successful in a cubicle environment. However, the Summit 5i would make an excellent switch for a lab or remote location where noise is not a factor. Both the Cisco 2950G and the SMC TigerSwitch are small enough and quiet enough to perform well in a cubicle environment. Both switches are solid performers and support most of the features used in Sandia's current environment. The only place where the SMC switch falls short is in the Security Access Control section (4.5). It doesn't support TACACS+ or RADIUS. If those functions are important, then the Cisco 2950G is the way to go. If TACACS+ and RADIUS are not required

functions, and eight 10/100BASE-T ports are sufficient (compared to twelve), then the SMC TigerSwitch is an excellent choice. It is by far the cheapest, having a list price under $400. It had the best latency performance compared to the other two switches. It is also the smallest and quietest and can easily sit on the corner of a desk with out taking up much room.

6. Acknowledgements

We would like to thank John Eldridge (9336) and Ron Olsberg (9336) who contributed greatly to the testing done for this paper. Their paper takes the same test plan and applies it to access-layer switches.

7. References

[1] Kevin W. Tolly, Glen R. Cory Jr., "VoIP, QoS and "Cubicle-class" LAN Switches", *ITclarity*, The Tolly Group, Manasquan, NJ, October 2002.

[2] Patrick L. Manke, "The Design/Evaluation/Development Area", Sandia National Laboratories Internal Report, Albuquerque, NM, November 2002.

[3] Catalyst 2950G-12 data sheet: http://www.cisco.com/en/US/products/hw/switches/ps628/products_data_sheet09186a00801a0c5b.html

[4] Extreme Summit 5i data sheet: http://www.extremenetworks.com/libraries/prodpdfs/products/summit5i.asp

[5] SMC TigerSwitch (SMC6709L2) data sheet (PDF): http://www.smc.com/drivers_downloads/library/SMC6709L2_DS.pdf

Appendix A: Test Results

Test #	Test Description	Cisco Catalyst 2950G	Extreme Summit 5i	SMC TigerSwitch (SMC6709L2)
1	**Functionality and Interoperability**			
1.1.	Port Capacity (10/100/1000 Mb)	12 10/100 ports	12 100/1000 ports	8 10/100, 1 1000 ports
1.2.	Monolithic Switch Module Availability	2 GBIC slots	4 GBIC slots	100BASE-FX,1000BASE-T
1.3.	VLAN Support	Pass	Pass	Pass
1.4.	802.1d	Compatible	Pass	Pass
1.5.	PVST+	Pass	Pass	Compatible
1.6.	PortFast	Pass	Not supported	Not supported
1.7.	802.1Q	Pass	Pass	Pass
1.8.	802.3ad	Pass	Pass	Pass
2	**Management and Diagnostics**			
2.1.	CLI	Pass	Pass	Pass
2.2.	Telnet In	Pass	Pass	Pass
2.3.	Telnet Out	Pass	Pass	Not supported
2.4.	Ping Out	Pass	Pass	Pass
2.5.	Web Interface	Pass	Pass	Pass
2.6.	SSH Ver. 1/2	Not supported	SSH Ver. 2	Not supported
2.7.	Switch Management Software	Pass	Not supported	Pass
2.8.	Switch Stacking	Pass	Not supported	Not supported
2.9.	SNMP Read	Pass	Pass	Pass
2.10.	SNMP Write	Pass	Pass	Pass
2.11.	Hot Swap	N/A	N/A	N/A
2.12.	Redundant Modules	N/A	N/A	N/A
2.13.	Port Mirroring	Pass	Pass	Pass
2.14.	File Upload/Download	TFTP	TFTP, BOOTP, SCP	TFTP
3	**Similarity to Cisco**			
3.1.	CLI Look & Feel	Cisco	CLI moderately different	Menu (easy), CLI (hard)
3.2.	Vty Password	Cisco	Not supported	Not supported
3.3.	Vty Enable	Cisco	Not supported	Not supported
4	**Performance**			
4.1.	Throughput (# of 1518 byte frames)	8127/81274 (100%)	8127/81274(100%)	8127 (100%)
4.2.	Latency (microseconds)	284.6/183.1	196.4/74.9	124.5/3.0
4.3.	Frame Loss Rate	0%	0%	0%
4.4.	Back-to-Back (# of 1518 byte frames)	16,254/162,548 (100%)	16,254/162,548 (100%)	16,254 (100%)
4.5.	Forward Pressure	(see Appendix B)	(see Appendix B)	(see Appendix B)
4.6.	Broadcast Forwarding	Pass	Pass	Pass
4.7.	Error Filtering	Pass	Pass	Pass
4.8.	Address Learning	Pass	Pass	Pass

5	**Security Access Control**			
5.1.	TACACS+	Pass	Pass	Not supported
5.2.	RADIUS	Pass	Pass	Not supported
5.3.	User Password	Pass	Pass	Admin only
5.4.	User Authorization Levels	Pass	Pass	Admin only
6	**Total Cost of Ownership**			
6.1.	List Price	$2,295	$10,995	$350.88
6.2.	Cost Per Port	$176.54	$845.76	$38.99
6.3.	Tech Support Cost	$185/year	$950/year	Free (life of product)
6.4.	Tech Support Hours	8x5xNBD	NBD	24/7
6.5.	Reliability (mean time between failure)	318,440 hours (predicted)	50,000 hours (minimum)	70,080 hours
6.6.	Availability (MTTR= one half hour)	99.99984%	99.9990%	99.99929%
6.7.	Warranty Period Hardware/Software	Limited Lifetime	1 year	3 years

Appendix B: Forward Pressure Results

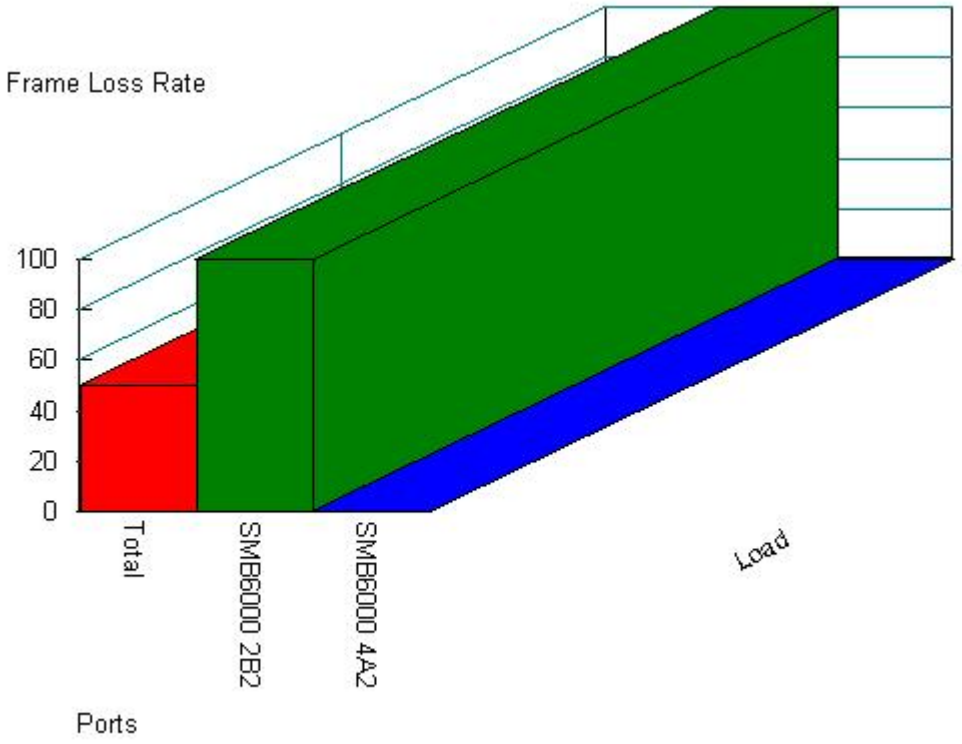

Figure 1: Cisco 2950G Forward Pressure Test Results

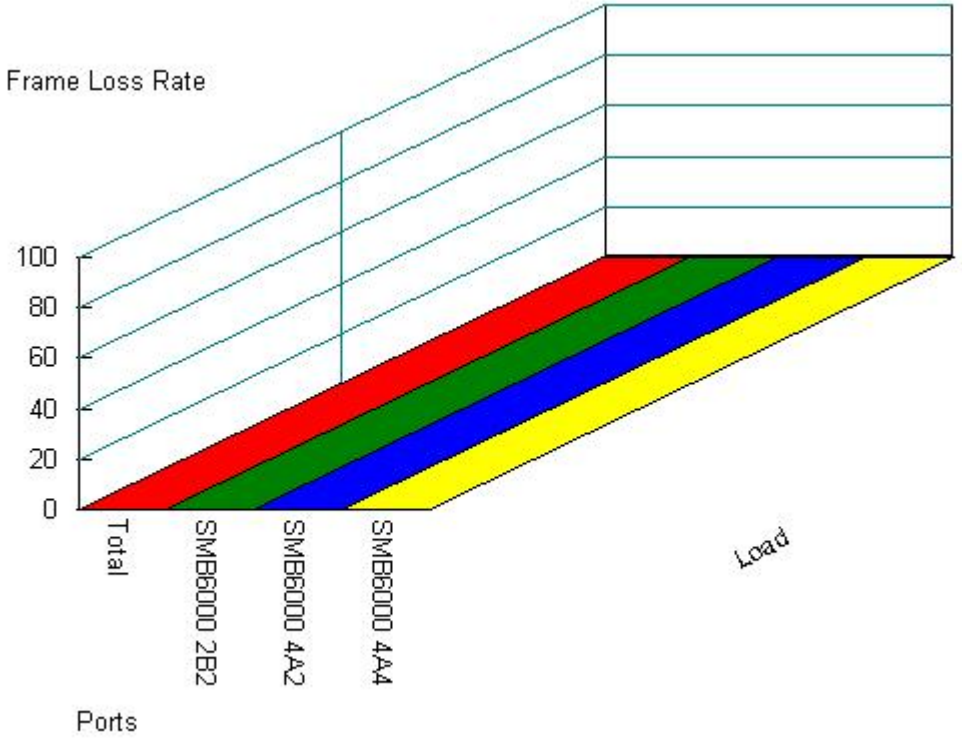

Figure 2: Extreme Summit 5i Forward Pressure Test Results

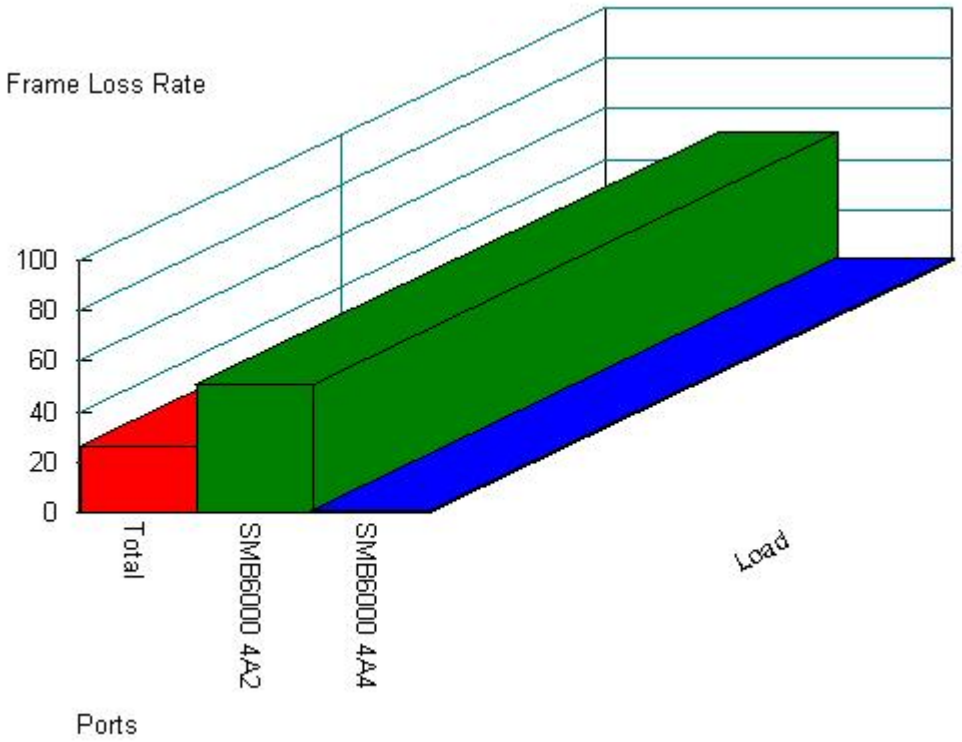

Figure 3: SMC TigerSwitch Forward Pressure Test Results

Explanation: Each number-letter combinations represents a **pair** of ports where one port receives traffic from the Smartbits test equipment and the other port sends traffic back to the Smartbits test Equipment. The Frame Lost Rate for the Cisco Catalyst 2950G's overall performance can be read at 50%. This is misleading though, since the GBIC ports on that switch would not communicate for that test (labeled 2B2). The loss was 100% for the GBIC ports and 0% (i.e. no loss) for the 10/100 ports (labeled 4A2). The Extreme Summit 5i showed no loss on its GBIC ports (2B2) or its 100/1000 ports (4A2 and 4A4). The SMC TigerSwitch showed close to 30% total loss with most the loss coming from ports 4A2 and very little from 4A4. This most likely indicates congestion in the backplane.

Note: The Forward Pressure test simulates congestion by sending packets with a smaller than legal interframe gap between each packet.

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