Test Summary

Radware

OnDemand Switch 1 & OnDemand Switch 2 AppDirector Version 1.06

Competitive Performance Evaluation versus F5 Networks BIG-IP 6800, BIG-IP 6400 and BIG-IP 1500

Premise: *Next-generation applications represent an evolution towards intelligent service management, generating more complex transactions that require deeper inspection levels. Such applications require platforms to operate at full capacity at Layer 7, while processing transactions with the fastest response time to meet SLA requirements and to assure the Quality of Experience.*

Radware commissioned The Tolly Group to evaluate the performance of its OnDemand Switches, the vendor's next-generation platforms that reportedly delivers over 3.7 Gbps.

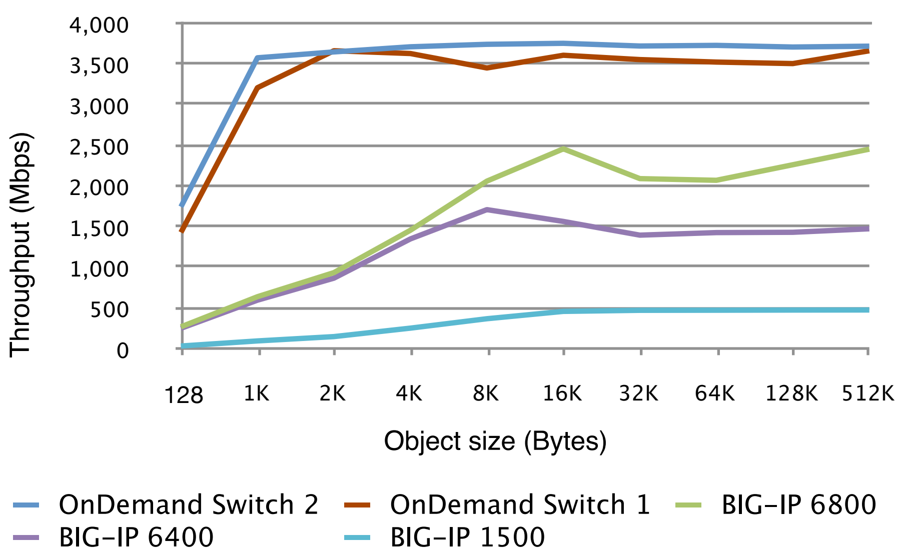
Engineers evaluated the performance of the OnDemand switches against F5 Network's BIG-IP 6800, BIG-IP 6400 and BIG-IP 1500 platforms. The goal was to measure performance while also handling challenging tasks, Layer 7 operations and transaction processing under DDoS attacks, and validate the readiness of the products for next-generation applications.

Engineers measured the transaction-per-second (tps) rate, throughput and response time for 10 object sizes at Layer 7 in multiple scenarios of a single HTTP request per connection and 10 HTTP requests per connection, while also testing the ability of the platforms to maintain performance while dealing with DDoS attack packets. Tests were conducted in February 2008.

Test Highlights

- Exhibits over 348K Layer 7 tps – more than 5X the transactions handled by F5's BIG-IP 6800 when handling 128-byte objects
- Delivers over 3.5 Gbps of throughput, while F5's BIG-IP 6800 reaches a maximum of 2.47 Gbps, when handling 10 HTTP transactions per connection and objects of 1-KB to 512-KB
- Exhibits an average of 6X better response time than F5's BIG-IP 6800 for most object sizes and 120X for 128-byte objects
- Combats 780,000 ICMP attack packets or 500,000 SYN attack packets while sustaining 1 Gbps of throughput with no performance degradation

Layer 7 Average Throughput (Mbps) at Various Object Sizes
Based on 10 HTTP Requests per Connection as Reported by Spirent Avalanche Commander



Source: The Tolly Group, February 2008

Figure 1

Executive Summary

Radware's OnDemand Switches routinely outperform the BIG-IP 6800 and smaller models during both Layer 7 performance and security tests.

Test results reveal a significant advantage for Radware's OnDemand Switch technology. Radware managed to outperform F5's BIG-IP platforms consistently across all test parameters.

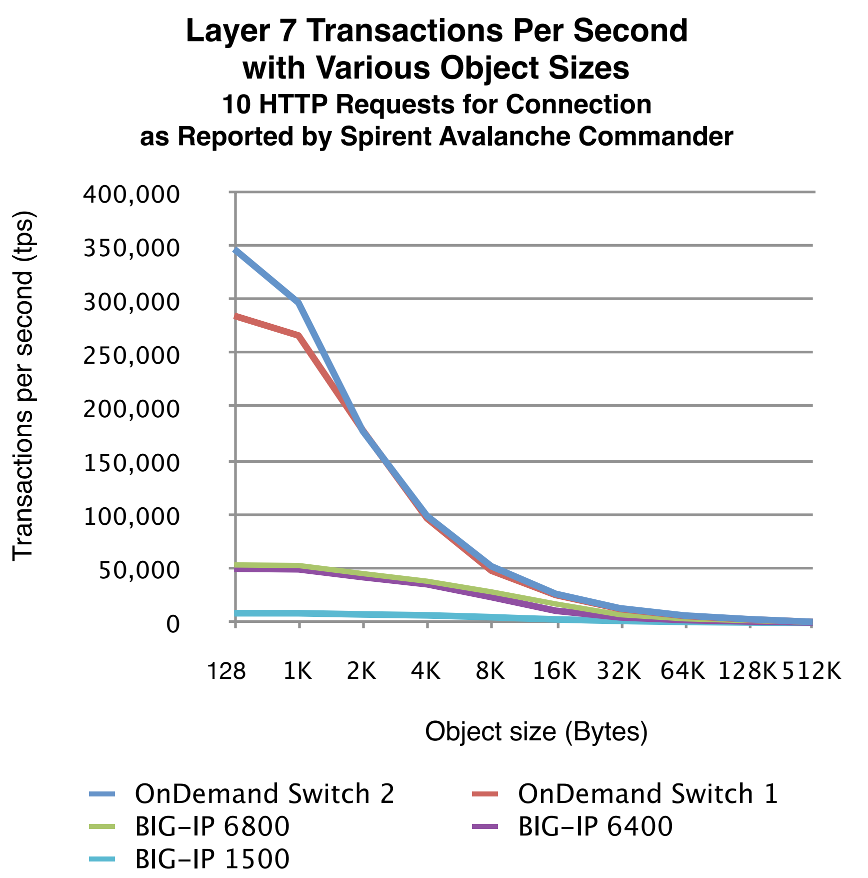
The OnDemand Switches presented a clear advantage in throughput and in transaction processing, while also presenting significantly faster response times. Latency figures observed, while testing F5's platforms, presented significant response time fluctuations that hold dramatic consequences for next-generation applications, such as voice, video, Oracle applications, SAP and even for the most basic scenarios of a browser's HTTP requests.

At Layer 7 with 10 HTTP requests per connection, the OnDemand Switch 2 achieved over 6X more transactions per second (tps), 120X faster response time and 6X more throughput than F5's 6800 — all while handling 128-byte objects.

The OnDemand Switch 2 handled an average of 348,095 tps for an average throughput of 1.76 Gbps and average response time of 0.032 milliseconds (ms) when handling 128-byte objects and 10 HTTP requests per connection (See Figures 1, 2, 3.). At 4KB packets, the OnDemand Switch 2 achieved throughput of 3.72 Gbps and processed 99,491 tps with an average response time of 1.65 ms.

By contrast, F5's BIG-IP 6800 was only able to attain 283 Mbps of throughput and process 53,953 tps with a response time of 3.88 ms when handling 128-byte packets and 10 HTTP requests per connection. That represents 6X less throughput compared to the OnDemand Switch 2 for 6.5X fewer transactions served. At 4KB packets, the F5 platform achieved throughput of 1.47 Gbps and processed 38,766 tps with an a 5.88 ms average response time.

Radware's OnDemand Switches demonstrated superiority across not only Layer 7 tests, but also under extreme DDoS attacks while keeping service levels set. Under sustained 1-Gbps traffic and zero service degradation, the OnDemand Switch 2 managed to handle over 500,000 SYN attack packets successfully compared to the BIG-IP 6800's 300,000 SYN attack packets. Additionally, the OnDemand



Source: The Tolly Group, February 2008

Figure 2

Switch 2 processed 783,000 ICMP attack packets, while F5's BIG-IP 6800 repelled only 400,000 ICMP attack packets. Overall, the OnDemand Switch 2 exhibited 30% better response time under DDoS attacks than F5's BIG-IP 6800.

Layer 7 Performance

Engineers set out to measure HTTP-aware load-balancing functions relative to two test scenarios: one and 10 requests per HTTP connection. In each test case, Tolly Group engineers measured throughput, tps rate and response time in milliseconds.

Layer 7 10 Requests Per Connection

In this test, the behavior of the different platforms was examined with a single connection carrying multiple HTTP transactions. Such a scenario is common for many applications ranging from simple browsing to voice applications using the Session Initiation Protocol (SIP).

The OnDemand Switches exhibited high levels of performance across all measured categories: transactions per second, throughput and response time.

While taking advantage of F5's optimized HTTP profile, the BIG-IP 6800, processed a maximum of 2.4 Gbps with a 512K object size. In comparison, both OnDemand Switches delivered over 3.6 Gbps of throughput across object sizes of 2 KB or higher. Additionally, Radware's OnDemand Switch 2 processed 348,096 tps for an object size of 128 bytes, in comparison F5's BIG-IP 6800 processed only 53,953 tps for an object size of 128 bytes. The OnDemand Switches maintained

Layer 7 Response Time in Milliseconds (ms)
10 HTTP Requests per Connection
as reported by Spirent Avalanche Commander

Object size (Bytes)	OnDemand Switch 2	OnDemand Switch 1	BIG-IP 6800	BIG-IP 6400	BIG-IP 1500
128	0.03	0.12	3.88	4.19	26.05
1K	0.08	0.14	3.88	4.17	25.97
2K	0.63	1.25	4.64	5.02	29.63
4K	1.65	3.45	5.88	12.82	33.47
8K	3.82	7.72	31.65	56.04	45.39
16K	8.14	10.52	34.23	52.20	72.45
32K	18.28	19.65	52.70	65.35	140.77
64K	37.25	37.30	96.64	111.55	330.34
128K	73.98	74.49	128.41	253.11	558.64
512K	287.78	287.92	410.69	698.16	2,234.21

Source: The Tolly Group, February 2008

Figure 3

Radware

OnDemand Switch 1/2

Layer 7 Switch Performance

TOLLY Up to Spec CERTIFIED

Product Specifications

Vendor-supplied information not necessarily verified by The Tolly Group

Radware OnDemand Switch 1 and OnDemand Switch 2

OnDemand Switch 1

- 4 Gbps of throughput
- On-demand throughput scalability
- On-demand service scalability
- Four Gigabit Ethernet ports (copper or fiber)
- Two redundant management ports providing out-of-band highly reliable management interfaces with enhanced security
- LCD panel displaying key statistics
- USB interface for software installation and recovery
- Multiple power supply configurations including dual, redundant AC/DC

OnDemand Switch 2

- 4 Gbps of throughput
- On-demand throughput scalability
- On-demand service scalability
- 12 Gigabit Ethernet ports + 4 Gigabit fiber ports (SFP-GBIC Mini)
- Two redundant management ports providing out-of-band highly reliable management interfaces with enhanced security
- LCD panel displaying key statistics
- USB interface for software installation and recovery
- Multiple power supply configurations including dual, redundant AC/DC

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their performance advantage across all object sizes and platforms with a gain of up to 6X more transactions per second.

Results show a more substantial advantage with respect to latency. OnDemand Switches delivered traffic 7X faster than the F5 products tested when handling 4 KB objects. For an object size of 8KB, the OnDemand Switch 2 delivered traffic with a response time of 3.82 ms, and OnDemand Switch 1 at 7.72 ms. In comparison, F5's BIG-IP 6800 delivered the same object size at 31.65 ms, BIG-IP 6400 at 56.04 ms and BIG-IP 1500 at 45.39 ms. The BIG-IP response times were anywhere from 8X to almost 15X slower than the Radware OnDemand switches for an 8KB object.

Results show that the BIG-IP 1500 introduces high levels of latency across all object sizes. In comparison Radware's OnDemand Switch 1 delivers traffic more than 8X faster.

Single Request Per Connection

Tolly Group engineers tested the the solutions ability to deal with a processing-intensive function of setting, inspecting and tearing down Layer 7 connections.

The OnDemand Switches held a considerable advantage over F5's tested platforms. While both OnDemand Switches managed to process over 3 Gbps of traffic across object sizes of 8KB or larger, F5's BIG-IP 6800 processed a maximum of 2.3 Gbps. The same behavior was
observed with the number of processed connections.

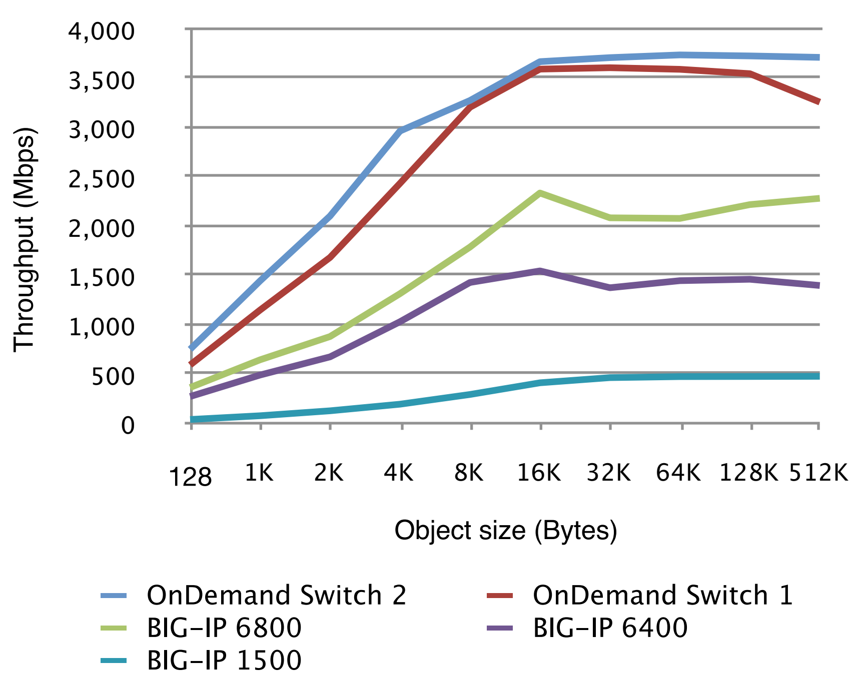
While the OnDemand Switch 2 processed 103,826 connections per second (cps) for 128-byte object sizes, F5's BIG-IP 6800 processed a maximum of 40,390 cps. Radware's OnDemand Switches managed to maintain a consistent advantage of over 2X the number of processed connections across object sizes of 8 KB or smaller.

A mandatory requirement for application processing is low latency. For financial applications, ERP, CRM, collaborative applications or any type of voice, video and many other applications, low latency is key. Radware's OnDemand Switches delivered better response times, ranging between 2X to 6X faster than F5's BIG-IP solutions.

F5's BIG-IP 1500 introduced poor response times across the entire tested object sizes. (See Figures 3 and 6.)

Test results show an increasingly high response time (i.e. using 50% of its capacity will result in 47 ms of latency) a figure that increases dramatically up to 2 seconds while using the device's full capacity, 500 Mbps. Such results introduce a major concern for applications relying on low latency. F5's BIG-IP 1500

Layer 7 Throughput (Mbps) With Various Object Sizes
One HTTP Request Per Connection as Reported by Spirent Avalanche Commander



Source: The Tolly Group, February 2008

Figure 4

presents poor performance
figures due to the scale of the solution; in contrast the OnDemand Switches maintain consistent low levels of latency for each of the throughput marks set by its OnDemand licensing model.

Security Results

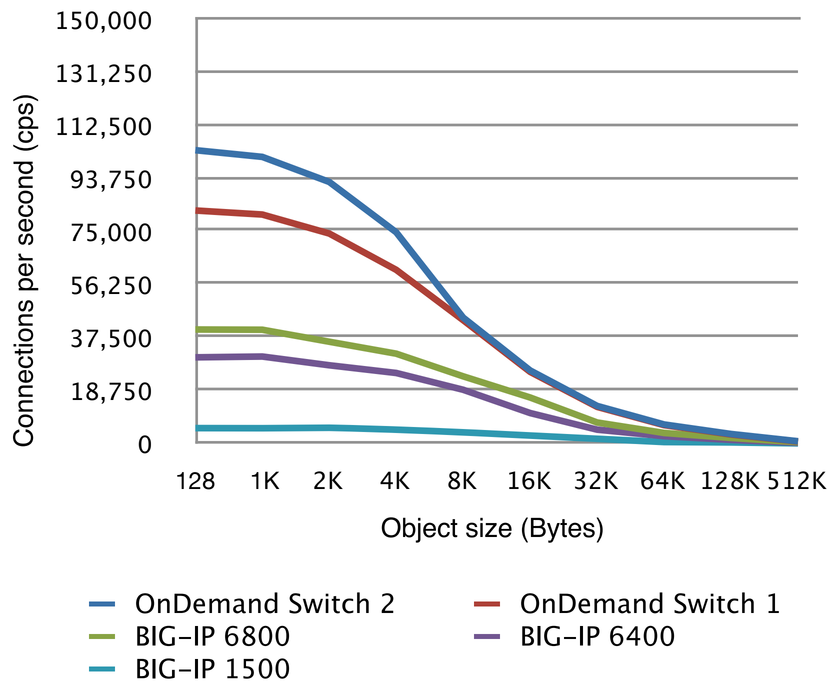
Distributed Denial of Service

This test demonstrates the ability of the platforms to sustain DDoS attacks, while maintaining service continuity. Both attack profiles were designed to dramatically affect the tested platform's available resources.

The tests demonstrate two classic DDoS attack scenarios and their capability to withstand attack packets that consume tremendous amounts of system resources.

Both tests were conducted with the objective of simulating real world scenarios, by taking advantage of 10,000 unique

Layer 7 Connection Rate (cps) with Various Object Sizes
One HTTP Request Per Connection as reported by Spirent Avalanche Commander



Source: The Tolly Group, February 2008

Figure 5

Layer 7 Response Time in Milliseconds (ms) One HTTP Request

Object size (bytes)	OnDemand Switch 2	OnDemand Switch 1	BIG-IP 6800	BIG-IP 6400	BIG-IP 1500
128	1.22	1.73	3.65	4.9	28.55
1K	1.24	1.77	3.75	4.97	28.85
2K	1.45	2	4.25	5.54	28.4
4K	2.19	2.89	15.58	6.17	33.14
8K	3.61	4.63	97.34	9.77	46.94
16K	8.13	13.61	160.52	18.29	69.99
32K	16.49	22.04	125.83	45.21	251.72
64K	33.67	42.13	145.5	87.28	265.7
128K	75.57	81.31	212.04	175.04	542.97
512K	144.65	161.73	469.6	361.41	2,215.23

Source: The Tolly Group, February 2008

Figure 6

sources, attacking the two vendor solutions. Both vendor solutions were challenged not by their ability to stop a simple uni-dimensional attack, but to measure the strength of their solutions for the following categories:

- Profiling and identifying the attack profile
- Containment
- Maintaining consistent service levels with sustained traffic of 1 Gbps
- Zero service degradation with zero errors or retransmissions

Such attacks are designed to overwhelm a target environment with no prejudice. Its objective is consuming the system's entire available resources to the point of delaying or even crashing a system/ service.

SYN Attack Results

Test results reflect the capacity of the tested products for dealing with SYN attacks while maintaining a regular course of an active service, with zero degradation.

Engineers utilized two tools for generating such a scenario. One generates a sustained traffic of 1 Gbps (with the exception of the F5 BIG-IP 1500, which used baseline traffic of 250 Mbps) and another generates the attack.

Radware's OnDemand Switches again outperformed F5's platforms. OnDemand Switch 2 and 1 blocked 500,000 and 460,000 SYN attack packets, respectively, compared to 300,000 for the BIG-IP 6800 and 100,000 blocked by the BIG-IP 6400, or 1/5th the capacity of the OnDemand Switch 2. (See Figure 7.)

F5's BIG-IP 1500 platform, utilizing a baseline of 250 Mbps, was able to block only 50,000 SYN attack packets, while introducing a dramatic increase in the overall response time of over 7X than observed in performing the same operation under regular circumstances.

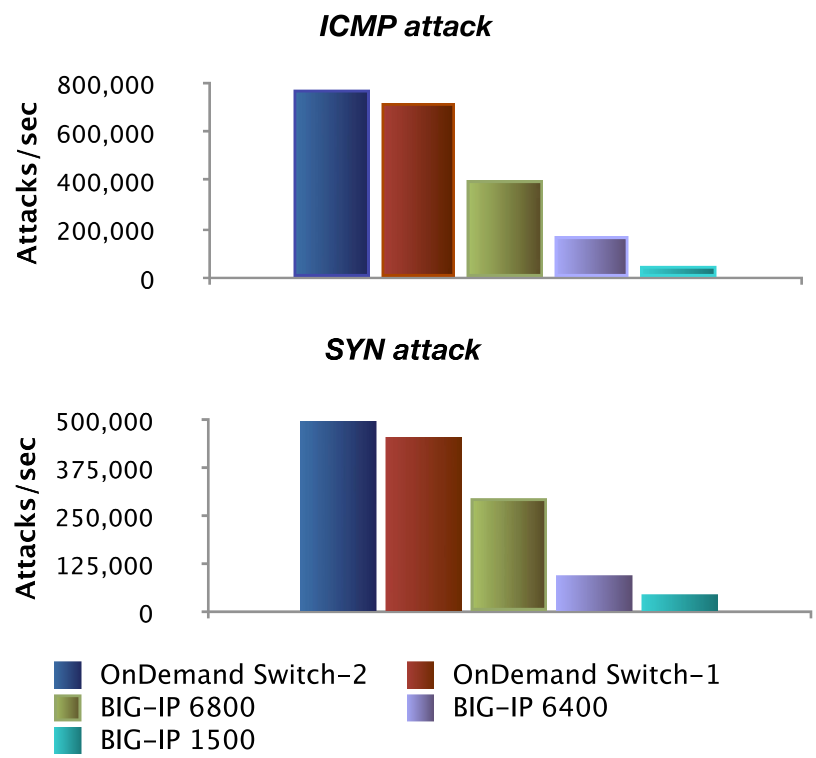
ICMP Flood Results

The ICMP flood test results were consistent with the previous SYN attack profile.

Radware's OnDemand Switches maintained consistent service levels under extreme attacks. The OnDemand Switch 2 and OnDemand Switch 1 processed 1 Gbps of sustained traffic with zero service degradation, under an attack of 780,000 and 720,000 ICMP attack packets, respectively. By comparison, F5's BIG-IP 6800 processed a maximum of 400,000 ICMP attack packets and BIG-IP 6400 managed only 180,000 ICMP attack packets.

Once again, F5's BIG-IP 1500 demonstrated low performance.

Maximum DDoS Attack Blocking Performance While Sustaining 1 Gbps of Legitimate Traffic
as Reported by Spirent Avalanche and SmartBits



Source: The Tolly Group, February 2008 *Figure 7*

The BIG-IP 1500, using the same baseline, blocked a maximum of 55,000 ICMP attack packets before dramatically affecting the service. In the previous SYN attack test, the greatest sign of distress was evident with a response time of 244 ms.

Test Setup & Methodology

The Tolly Group tested Radware's OnDemand Switch 1 and OnDemand Switch 2 running the vendor's AppDirector 1.06 software against a trio of F5 Networks switches: the BIG-IP 6800, BIG-IP 6400 and BIG-IP 1500. (See Figure 8 for software version info.)

The test bed for the ODS 1 and ODS 2 switches, and for the BIG-IP 6400 and BIG-IP 1500 switches consisted of two Spirent Avalanche 2700 pairs, connected to a Cisco Catalyst 3560G-48 using copper cables. The DUT was connected as well to the same Cisco switch. During the audit, the Avalanche Commander 7.51 was configured using a SimUser load profile.

Tolly Group engineers used four Avalanche pairs to ensure the test bed devices would not serve as a performance bottleneck.

With this configuration, engineers generated around 280,000 cps, which was significantly more than the DUT's capability. For the audit, engineers used a CPS load profile.

Switches Under Test	
Vendor	Product/Version
F5 Networks	BIG-IP 6800, 9.4.2 Build 228.18 Final
F5 Networks	BIG-IP 6400, 9.4.2 Build 228.18 Final
F5 Networks	BIG-IP 1500, 9.0.4 Build 118.5
Radware	OnDemand Switch 2, ver. 1.06
Radware	OnDemand Switch 1, 1.06

Source: The Tolly Group, February 2008 *Figure 8*

For the Layer 7 performance tested with a single HTTP request, Tolly Group engineers used a Spirent Communications Avalanche 2700 to simulate the client side and Reflector 2700 to simulate the server side. Engineers configured the Avalanche tool so each client initiated one GET request for one HTTP transaction per connection test and 10 GET requests for 10 HTTP transactions per connection test.

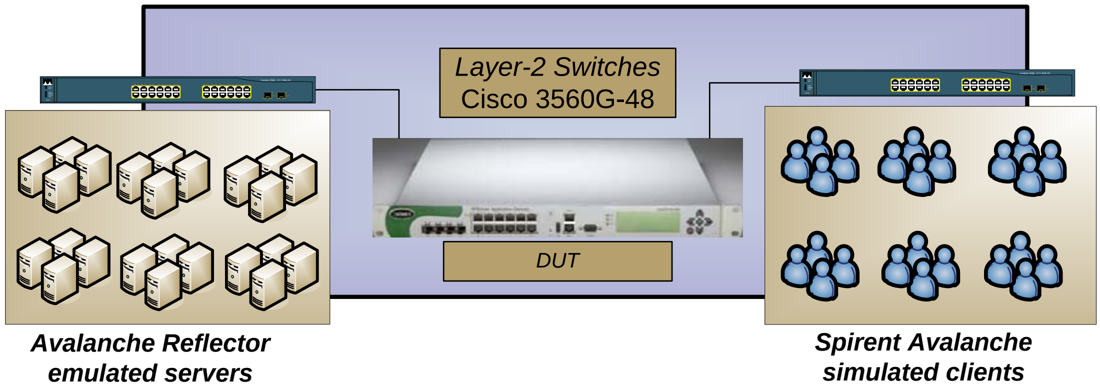
Note that the "Transaction-Profile" parameter defined the size of the object that was returned from Reflector.

The Avalanche load profile was configured for four (4) phases: 0) Delay, 1) Ramp Up, 2) Steady State, and 3) Ramp Down. The role of phase 0 and 1 was to allow the DUT time to recognize all the servers. Phase 3 (Steady State) used 300 seconds on all tests. The final results represent an average of the steady state numbers yielded.

For the security test, engineers used SmartBits to inject the SYN/ICMP attack packets; to generate legitimate traffic, engineers used an Avalanche 2700.

The objective of the test was to measure the maximum SYN/ICMP attack traffic that a DUT could block without affecting the legitimate traffic. First, engineers initiated the legitimate traffic using the Web Avalanche and once the devices reached a steady state, engineers injected attack packets. During steady-state, engineers determined that the devices tested were able to sustain 1 Gbps of legitimate traffic while blocking SYN/ICMP attack packets in the background.

Test Bed Diagram



Source: The Tolly Group, February 2008 *Figure 9*

Fair Testing Charter™
Interaction with Competitors

Radware acquired the F5 Networks BIG-IP appliances via normal product distribution channels. The Tolly Group invited representatives from F5 Networks to participate in the testing as per The Tolly Group's Fair Testing Charter (See http://www.tolly.com/FTC.aspx). Representatives from F5 Networks did not respond to the invitation. However, The Tolly Group went an extra step and consulted an F5 BIG-IP expert regarding the configurations for Layer 7 and Security tests. The expert verified that the configurations for the BIG-IP appliances were set for the maximum performance at every given test.

The Tolly Group is a leading global provider of third-party validation services for vendors of IT products, components and services.

The company is based in Boca Raton, FL and can be reached by phone at (561) 391-5610, or via the Internet at http://www.tolly.com, sales@tolly.com

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