TEST REPORT

Tolly.

#220138

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Commissioned by

VMware, Inc. & Intel

VMware Work From Home

Performance, VoIP and Microsoft 365 User Experience Evaluation

EXECUTIVE SUMMARY

The flexibility and ease-of-use of SD-WAN has made it extraordinarily popular as the "next-gen" WAN for organizations large and small. SD-WAN's network overlay topology can also provide significant benefits for end-user experience while maintaining solid throughput performance. VMware SD-WAN™ can remediate packet loss and deliver a high-quality experience even under adverse network conditions.

VMware commissioned Tolly to benchmark the quality-of-service and remediation capabilities of VMware SD-WAN to improve the end-user experience for voice-over-IP (VoIP) and work-from-home (WFH) applications. Additionally, Tolly benchmarked the packet throughput of VMware SD-WAN.

VMware SD-WAN demonstrated significant benefits for both VoIP and WFH use cases in packet loss scenarios. Furthermore, testing verified throughput performance as described in the VMware SD-WAN specification sheet. See Figure 1.

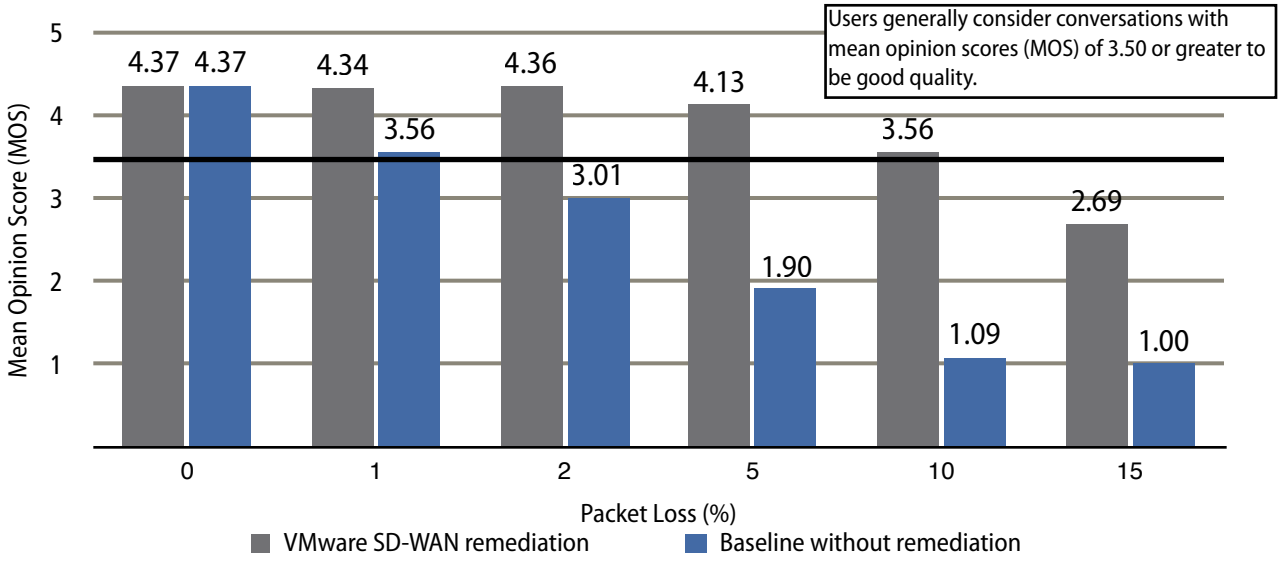
THE BOTTOM LINE

VMware SD-WAN:

1. Remediated packet loss for VoIP traffic, delivering a good user experience even with packet loss of 10%
2. Matched data sheet specifications for throughput, delivering 350Mbps for 1300-byte packets
3. Improved download time by up to 71% via packet loss remediation for Microsoft 365 (M365) OneDrive download

VoIP Quality vs. Packet Loss - VMware SD-WAN Edge to Hub

(As reported by Keysight IxChariot)



Note: Apposite Tech. Netropy used to generate network impairments. G711u session used for voice traffic.

Source: Tolly, November 2020

Figure 1

Test Results

VoIP Quality

VoIP is an essential communication tool for distributed organizations. While the bandwidth requirements for a single conversation is low (about 64Kbps), voice quality can be negatively impacted by packet loss that can occur as the packets transit the internet.

For years, the mean opinion score (MOS) has been a standard method for measuring voice quality and has been integrated into standard voice-quality testing tools. Generally, a MOS of 3.50 or higher is considered a good quality conversation and scores of 3.00 or lower are unacceptably poor.

Test Overview

In this test, Tolly used Keysight IxChariot in conjunction with the Apposite Technologies Netropy to benchmark the voice quality of conversations subjected to increasing levels of packet loss with and without VMware SD-WAN packet loss remediation. Tests used a single G.711u voice session. Tests were run at six different packet loss levels from no loss up to 15% loss.

Baseline Results

Tests show that even packet loss of 1% immediately degraded the voice quality of the baseline tests run without VMware SD-WAN remediation. The baseline dropped down to 3.56, near the minimum score for good quality conversations. See Figure 1 for all voice quality results.

When packet loss was increased to just 2%, the baseline results slipped into unacceptable quality with a MOS of 3.01. With packet loss of 5% and above, the baseline MOS quality drops quickly to a level where a conversation would not even be intelligible, and thus, useless.

VMware SD-WAN Results

The same set of tests were run through the VMware SD-WAN solution using the default policies that provide on-demand remediation for packet loss.

Real time applications such as voice or video flows can benefit from Forward Error Correction (FEC) techniques when there is packet loss. Dynamic Multipath Optimization™ (DMPO) automatically enables FEC on single or multiple links. With on-demand remediation in place, VMware SD-WAN detects packet loss in the network and sends duplicate packets to remediate that loss.

With 1% loss, the score of 4.34 was virtually identical to the baseline, zero loss MOS of 4.37. Thus, the benefits of VMware SD-WAN packet loss remediation are immediately evident.

As packet loss was increased the results were even more impressive. With loss of 2%, MOS remained effectively the same at 4.36 where the baseline results had already dropped to 3.01. With 5% loss, VMware SD-WAN-remediated VoIP MOS was at 4.13 and remained in the "good" zone of 3.56 even with 10% packet loss.

Packet Throughput

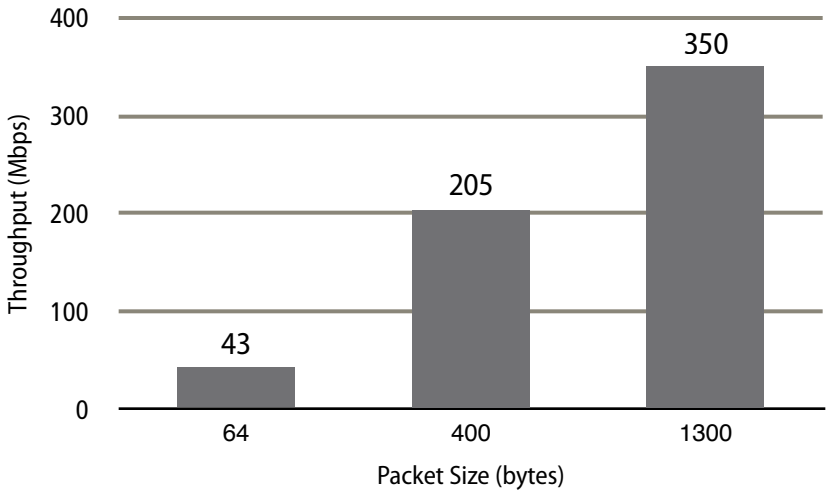
Raw packet processing power is always of interest to network architects as it is essential for them to understand the effective bandwidth capacity between network nodes.

Test Overview

In this test, Tolly used Spirent TestCenter to generate traffic carried between a pair of VMware SD-WAN nodes to benchmark the

Bidirectional Throughput - VMware SD-WAN Edge to Hub

(As reported by Spirent TestCenter)



Note: 400-byte test used the iMix traffic profile with average size of 400-bytes. Single Gigabit Ethernet connection used on each VMware SD-WAN appliance.

Source: Tolly, November 2020

Figure 2

zero-loss packet throughput at small, large and a mixture of packet sizes.

VMware SD-WAN Results

The VMware SD-WAN results matched the product specifications. The pair of network nodes delivered 43Mbps at 64-byte packets, an average of 205Mbps with an iMix traffic stream with a 400-byte average packet size and 350Mbps with 1300-byte packets. See Figure 2.

Microsoft 365 - WFH - Download Speed

Working from home became a reality for almost every organization and knowledge worker in 2020. Maintaining productivity is key for the home-bound worker. A reliable, high-quality internet connection is essential for making a productive environment - but connections are not always reliable. As noted earlier, packet loss on the internet - which is beyond the control of the end-user - can have a negative impact directly and indirectly on productivity. Long waits for downloads to complete delays users from working with those files.

Where the VoIP test measures the impact of packet loss and remediation on a low-bandwidth, low packet count application, this test focuses on a high-bandwidth, high packet count application.

Test Overview

In this test, Tolly used the Aukua Networks MGA2510 Ethernet Test and Monitoring Platform configured as a network impairment emulator to measure the impact of packet loss and remediation on file download. Tests were run at four different packet loss levels from no loss up to 8% loss. This test ran across a single VMware SD-WAN spoke to M365 SaaS.

The test scenario measured the download time of a ~250MB mp4 video file from the OneDrive component of M365.

Baseline Results

Tests show that even packet loss of 2% can have a significant negative impact on file download times. Download time degraded by a factor of 20 going from 37 seconds with no packet loss to 741 seconds or over 12.5 minutes when loss was introduced. See Figure 3 for all WFH download results.

At packet loss levels of 5% and 8% the download was even slower requiring 780 seconds (13 minutes) and 844 seconds (14+ minutes) respectively.

VMware SD-WAN

Performance & User Experience

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Tested November 2020

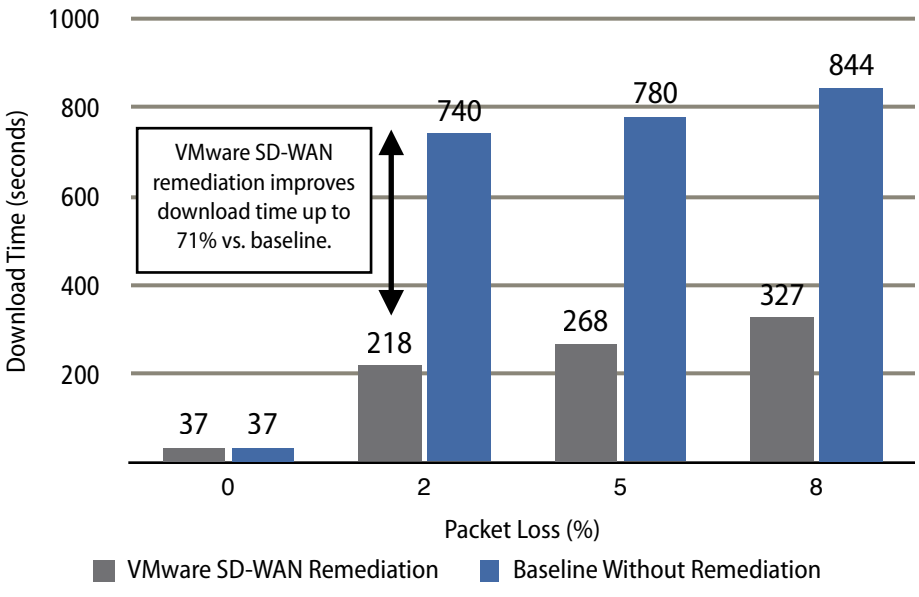
VMware SD-WAN Results

The same set of tests were run through the VMware SD-WAN solution using the default policies that provide on-demand remediation for packet loss.

Dynamic Multipath Optimization (DMPO) automatically detects the packet loss and M365 download that is taking place. In this situation, TCP applications such as file

M365 WFH Download vs. Packet Loss - VMware SD-WAN Edge to SaaS

(Lower numbers are better/faster)



Note: Video file of ~250MB downloaded from M365 OneDrive.

Source: Tolly, November 2020

Figure 3

transfer would benefit from Negative Acknowledgement (NACK). With on-demand remediation in place VMware SD-WAN detects packet loss in the network and retransmits the missing packets to remediate that loss.

As with the VoIP quality test VMware SD-WAN remediation improves the download times dramatically compared to the baseline.

With 2% loss VMware SD-WAN improves the download speed by 71% over the baseline.

Similar improvements are seen in the other scenarios with VMware SD-WAN improving download time by 66% with 5% loss and 61% with 8% loss. With VMware SD-WAN remediation in place even users experiencing significant packet loss on their internet connections will get faster downloads than without remediation.

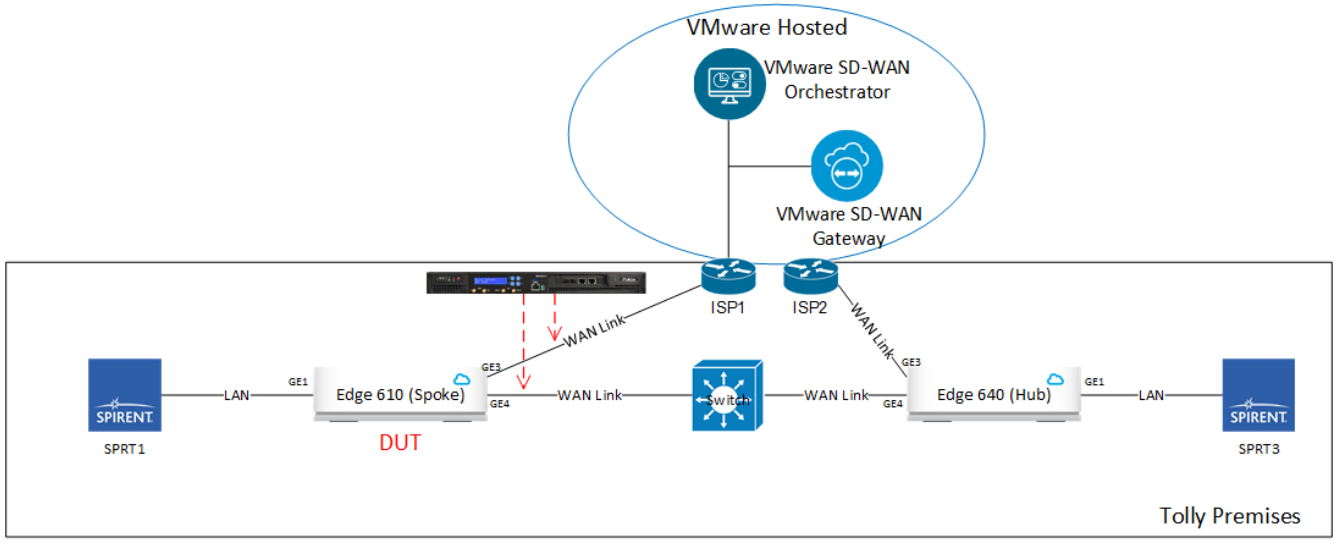
Advantages from Intel Developer Tools and Technologies

Co-engineering by VMware and Intel has built optimizations into the solution using the Intel developer tool set, taking advantage of capabilities built into the Intel platforms used for the SD-WAN appliances. The Intel developer tools and technologies include the following:

- **Data Plane Development Kit (DPDK)** is a library of open standard software drivers originally developed by Intel that drive up packet-processing performance by routing network packets around the Linux kernel.
- **Intel® QuickAssist Technology (Intel® QAT)** provides a software-enabled foundation for security, authentication, and compression, significantly increasing performance and efficiency.
- **Intel® AES New Instructions (Intel® AES-NI)** accelerates key parts of the encryption algorithm in hardware, making pervasive, end-to-end encryption possible without degrading performance.

Source: VMware & Intel

VMware SD-WAN Test Bed



Note: Not all components were used for all tests.VoIP tests used Keysight IxChariot in conjunction with Apposite Tech Netropy for network impairments. WFH scenario used Aukua MGA2510 as the network impairment emulator.

Source: Tolly, November 2020

Figure 4

Test Setup & Methodology

The focus of the test was to benchmark both the effectiveness of the VMware SD-WAN quality-of-service packet loss remediation implementation along with the raw packet throughput of the VMware SD-WAN appliances.

Test Environment

The voice quality tests and packet throughput tests were run using a pair of VMware SD-WAN appliances. The WFH download test was run using a single VMware SD-WAN spoke appliance accessing the M365 SaaS application. Figure 4 illustrates the overall test bed. Details can be found in Tables 1-4.

VoIP Quality Tests

Two sets of IxChariot clients were used for this test. One pair connected to each of two VMware SD-WAN appliances which were connected to two ports of the Netropy impairment generator. These would be used to provide remediation results. The other client pair were connected directly to the impairment generator and were used to provide the baseline results. Tests were run for two minutes at each packet loss level.

Test Infrastructure Details

SD-WAN Infrastructure Under Test

Vendor	Device	Device Type	GbE Ports	Version
VMware	VMware SD-WAN Edge 640	Hub	6	3.4.3
VMware	VMware SD-WAN Edge 610	Spoke	6	3.4.3

Table 1

VoIP Voice Quality Test

MOS Test Application	
Vendor	Keysight
Application	IxChariot v9.6.16.51
Clients	Ubuntu Linux
Traffic Information	Single G.711u session (64Kbps)
Network Impairment Generator	
Vendor	Apposite Technologies
Product	Netropy N91 v4.0.2.3
Packet Loss	Random

Table 3

Packet Throughput Test

Traffic Generator	
Vendor	Spirent
Platform	Spirent TestCenter/Avalanche
Ports	2X Gigabit Ethernet
Packet Sizes	64 and 1300-bytes, iMix

Table 2

WFH Download Test

Client	Microsoft Windows 10 with GbE LAN connectivity
Network Impairment Generator	
Vendor	Aukua Systems
Product	MGA2510 Ethernet Test Platform
Packet Loss	Random

Table 4

Source: Tolly, November 2020

Tables 1-4

Packet Throughput

Throughput tests were run with bidirectional traffic between two ports on the DUT. The two ports were configured in L3 routed mode. Aggregated throughput of the bidirectional traffic was reported in each test.

Engineers used the RFC2544 wizard in Spirent TestCenter to test 64-byte and 1300-byte frame size throughput. To further evaluate application throughput, engineers created different applications (HTTP, HTTPS, DNS and SIPng) in Spirent Avalanche. The average frame size of the iMIX application traffic was ~400-bytes.

M365 - WFH - Download Speed

Tests benchmarked the download time of a 253MB video (mp4) file from M365 OneDrive to the client machine at three packet loss levels. Tests were run three times and the average result was used.

Test Equipment Summary

Vendor	Product	Web	
Apposite Technologies	**Netropy**	https://apposite-tech.com	
Aukua Systems	**MGA2510 Ethernet Test Platform**	https://www.aukua.com	
Keysight	**IxChariot**	https://www.ixiacom.com	
Spirent Comm.	**TestCenter**	https://www.spirent.com	

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