

Dell PowerMax 64G Enterprise Storage Solution

Dell PowerEdge 17G with Marvell QLogic HBA, Connectrix MDS Directors, & PowerMax 8500

EXECUTIVE SUMMARY

Modern data centers require storage infrastructure that delivers consistent performance, seamless interoperability, and robust resilience. As organizations deploy increasingly complex applications and workloads, the integration between servers, host bus adapters (HBAs), SAN FC directors, and storage arrays becomes critical to overall system reliability and performance.

Dell commissioned Tolly to evaluate the integrated capabilities of a joint solution featuring Dell PowerEdge 17th Generation servers with the Marvell QLogic QLE2872C 64G FC HBA, Dell Connectrix MDS 9700 Enterprise Directors from Cisco Systems, and a Dell PowerMax 8500 64G storage array. This evaluation focused on demonstrating the "better together" benefits when these Dell, Marvell, and Cisco Systems components are deployed as an integrated 64G FC solution.

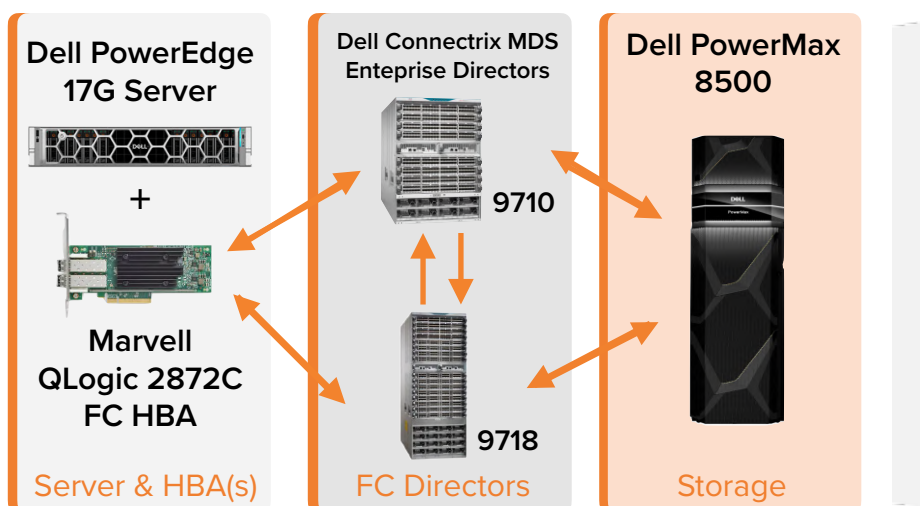
Testing demonstrated seamless interoperability across all components with automatic link speed negotiation and LUN discovery without manual intervention, while exhibiting robust resilience during fault scenarios. Advanced congestion management with autonomous mitigation successfully maintained Quality of Service (QoS) during high-utilization periods, providing organizations with a comprehensive 64G FC infrastructure combining proven interoperability, automated resilience, and advanced management capabilities in a unified platform. See Figure 1 for more details.

THE BOTTOM LINE

Dell PowerMax 64G Enterprise Storage Solution:

- 1 Comprehensive 64G Fibre Channel (FC) interoperability with seamless link negotiation and Logical Unit Number (LUN) discovery, congestion notifications across Dell, Marvell, and Cisco components
- 2 Automated resilience with rapid failover and recovery capabilities ensuring high availability for mission-critical workloads
- 3 Advanced congestion management through use of industry-standard congestion notification frames, Virtual Lanes collaborative technology, and I/O throttling
- 4 Integrated security and deep analytics capabilities providing end-to-end protection and visibility for Storage Area Network (SAN) environments

64G Storage Area Network (SAN) Architecture Under Test



From Server to Storage,
Dell's Unified 64G-
Enterprise Solution
Minimizes Infrastructure
Complexity While
Maximizing Mission-
Critical Uptime

Note: The Dell Connectrix MDS 9700 Enterprise Directors are made by Cisco Systems.
Source: Dell, Tolly, October 2025

Figure 1



Background

Multi-vendor, multi-component environments are the norm, rather than the exception. Customers need to have confidence that all of the components will work together to provide not only basic functionality, but advanced use cases for modern data centers. To that end, Tolly has conducted this test to model a proof of concept that one might find in practice.

Environment Overview

32G/64G are the foundation for mission-critical apps, with many just now migrating to 64G, offering customers unmatched lifecycle value. Testers built a microcosm of a 64G enterprise storage solution. This consisted of a single Dell 17G server connected via two ports of a single, dual-port HBA to different Dell Connectrix MDS 9700 Enterprise directors.

The Connectrix directors were connected via two links, configured as a port channel, to create a single, redundant fabric. Enterprise directors provide enhanced reliability and functionality compared to fixed-configuration FC switches. MDS directors have a modular chassis that takes supervisor modules, fabric (crossbar) modules, and line cards. With dual supervisors, multiple fabric modules, and multiple PSUs, there is no single point of failure. The directors are essential for mission-critical applications at 32G/64G¹.

A Dell PowerMax 8500 Array was connected to each of the two FC directors. The Dell 17G server was running RHEL 9.x and configured for multipath I/O.

Results

Interoperability

SANs are demanding and often complex environments. It is essential that storage solutions comprised of elements from different providers interoperate appropriately. These tests illustrate key interoperability features of the Dell, Cisco Systems, and Marvell QLogic technology. A summary of all results can be found in Table 1 on page 4.

Bandwidth / Link Speed Negotiation

The Connectrix MDS 9700 Enterprise Directors were populated with modules capable of 64G. For legacy customers, the directors also support port speeds from 4G to 32G. Testing demonstrated seamless interoperability across all components with automatic link speed negotiation at 64G.

Logical Unit Number (LUN) Discovery

LUN discovery occurred without manual intervention across the integrated solution. The Dell PowerMax 8500 storage array seamlessly presented logical units to the Dell PowerEdge server through the Dell Connectrix MDS SAN fabric, with proper multipath detection and configuration occurring automatically.

Congestion Control

Tested separately and discussed further down, the solution demonstrated interoperability for congestion notification across the fabric using the industry-standard Fabric Performance Impact Notification (FPIN) frames.

Resilience

Automatic and rapid recovery from component outages is essential in maintaining expected levels of availability and performance. The test environment was configured to have redundant paths from end-to-end.

HBA Port Resilience

As part of the server's multipath I/O subsystem, the dual-port HBA supports mapping a single LUN (disk) across multiple HBA ports. Not only can this be used for load balancing the traffic but it provides resilience against a port failure.

Engineers demonstrated this by first generating steady-state storage traffic. This traffic traversed both ports to the target LUN. One port was disabled via its connected port. Engineers confirmed that traffic continued to flow over the remaining port.

Finally, the port in question was re-enabled. Engineers noted that the port automatically became available and active once more.

HBA Adapter Resilience - Port Isolation

While invisible to the user, Marvell QLogic architects its dual-port adapters as essentially two standalone adapters sharing the same PCIe bus². Not only does each port have its own firmware, memory, and scheduler, each port has a dedicated processor. This means that a failure to any of these components will bring down only one port and not both ports of the adapter. Other vendors share resources across the two ports thus exposing both ports to failure if a single key component fails.

To test this capability, engineers used the Linux kernel "remove" function which is the

¹ <https://www.cisco.com/c/en/us/products/collateral/storage-networking/mds-9700-series-multilayer-directors/mds-9000-five-reasons.html>

² <https://www.marvell.com/content/dam/marvell/en/public-collateral/fibre-channel/marvell-qLogic-fibre-channel-port-isolation-architecture-technology-brief.pdf>

equivalent of hot-unplugging a physical port. Engineers noted that traffic continued to run on the remaining port.

Because this command works at the PCIe function (associated with the HBA Port) level, the fact that the remaining port was unaffected provides proof that the ports function as separate adapter cards and are thus isolated from one another. The Linux kernel “rescan” function was used to rediscover the PCIe function associated with the HBA port. Engineers noted that traffic then began flowing once again over the port that had previously been removed.

FC Director Fabric Resilience

When two or more FC directors are connected with two or more port channel links between each pair, the directors form a resilient network fabric.

To validate this feature, engineers connected one port of the Marvell QLogic HBA in the Dell 17G server to “Director A” and connected one port of the Dell PowerMax 8500 to “Director B.” The second ports on both the server and the storage array were disabled so that the only “end-to-end” path required traversing the director-to-director, dual-link port channel connection. The port channel links shared the director-to-director traffic load.

With traffic running, testers disabled one of the two ports. There was no disruption to the traffic flow as the remaining link seamlessly continued to carry the traffic. The traffic generation program continued to run without issue.

FC Director Redundant PSU Resilience

When a FC director is deployed with multiple power supply units, those additional units

can automatically provide resilience should a single power supply fail.

This test was run in the same fashion as the prior fabric resilience test. Again, with traffic running across the director, one of the power supplies was taken offline via a console command. As with the prior test, there was no disruption to the traffic flow and the traffic generation program continued to run without issue.

Storage Port Resilience

When hosts are configured to use multipath I/O, the OS creates a pseudo device that allows a single logical target to be accessed via multiple physical paths. The Dell PowerMax 8500 was configured with two ports connecting to different FC directors of the same logical fabric. Both ports of the PowerMax 8500 were active simultaneously, with each port being able to provide connectivity should the other port fail for any reason.

With traffic running across the active port, the active port was disabled via a console command. There was no downtime when one of the active ports was disabled. Traffic continued to run over the remaining active port. The traffic generation program continued to run without issue.

Congestion Management

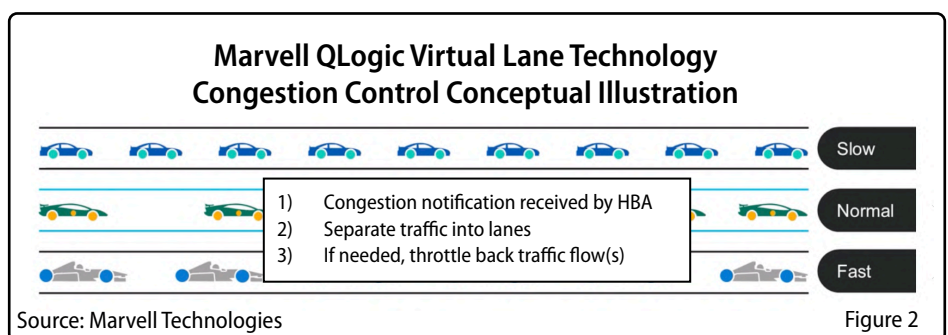
Autonomous congestion management successfully maintained Quality of Service (QoS) during high-utilization periods, providing organizations with a comprehensive 64G FC infrastructure combining proven interoperability, automated resilience, and advanced traffic management capabilities in a unified platform.

Marvell QLogic USCM

Marvell QLogic Universal SAN Congestion Management (USCM)³ is a collaborative fabric-to-end-point flow control/congestion management architecture that optimizes performance for environments where slower devices and/or “bursty” application traffic can cause congestion. It is implemented using Fabric Performance Impact Notification (FPIN) messages from the director to initiator ports to monitor buffer credit depletion. In response to such messages, Marvell QLogic uses virtual lane technology and traffic throttling to manage the congestion.

Marvell QLogic Virtual Lane Technology

Traditionally, the FC-to-HBA port connection functions similarly to a single-lane highway. Traffic from different sessions are handled serially. For environments with mismatched FC speeds, for example, a combination of NVMe (flash) and HDD storage, or where



³ <https://www.marvell.com/content/dam/marvell/en/public-collateral/fibre-channel/marvell-fibre-channel-uscm-tech-brief.pdf>



latency-sensitive transactions have to share a port with database backup or logging functions, this could be problematic.

Virtual Lane technology is a cooperative solution between HBA and director port. It functions similarly to a multi-lane highway. Traffic can be treated as fast, normal, or slow and can be queued and processed accordingly. This removes slow traffic from impeding other more critical traffic. See Figure 2 for a conceptual illustration.

This is new technology that requires the Marvell QLogic QLE2870 Series HBA (or the 32G QLE2770 Series HBA) with firmware version 9.12.00 or later. The Connectrix MDS

director must have NX-OS 9.3(2) or later. Both the Connectrix MDS FC director and the HBA must be configured appropriately to use Virtual Lane technology.

To illustrate virtual lanes, engineers started the test generating traffic at near line-rate. The virtual lane assignment was monitored through the kernel sysfs file created by Marvell HBA driver.

To simulate congestion and trigger virtual lanes, engineers manually sent FPIN (congestion notification) frames to the initiator HBA from the director.

Linux log files were examined to confirm receipt of the FPIN frames. Then, the virtual lane assignments were monitored to confirm that the virtual lane had been updated and that impacted traffic had been quarantined to the “slow” lane.

Bandwidth Throttling

In cases where virtual lane assignment requires further mitigation to resolve the congestion situation, the adapters will automatically begin to reduce (“throttle”) the traffic being transmitted from the HBA. Engineers observed reduction of the outbound traffic load once throttling was triggered. The bandwidth was reduced to less

Dell-Marvell-Cisco Storage Area Network Solution Summary Results

Area	Test Case	Description	Result
Bandwidth Demonstration	64G	End-to-end 64G Fibre Channel connectivity	✓
Interoperability	Link Negotiation	Auto-sense of server HBAs, FC directors and storage array to highest support link speed	✓
	Logical Unit Number (LUN) Discovery/ Multipath	Automatic mapping of disk resources and access via multiple paths using multipath pseudo device	✓
	Fabric Performance Impact Notification (FPIN) Congestion Notification	Connectrix MDS director fabric proactively notifies host HBA about performance issues on the network data path. (This is both a congestion and interoperability feature.)	✓
Resilience	Marvell QLogic Dual-port HBA Port Resilience	Multipath support automatically redirects traffic to use the remaining operational port (which was already active transmitting traffic)	✓
	Marvell QLogic Dual-port HBA Adapter Resilience	Architected as two logically-separate adapters on a single physical adapter allows one port to be removed at the OS PCI level without impacting the other logical adapter where traffic continued to pass	✓
	Connectrix MDS FC Multi-Director Fabric Resilience	Removal of a single port of a port channel pair does not impact traffic flow across the director fabric	✓
	Dell Storage Array Port Resilience	Multipath support provides for automatic recovery with zero down time	✓
Congestion Control	Virtual Lane Technology - Host / Fabric Congestion Management & Bandwidth Throttling	Fabric and host HBA dynamically migrate traffic to different lanes based on congestion detected in the network. “Single-lane” legacy session flow transformed into a “multi-lane” environment allowing traffic to be prioritized & quarantined as fast/normal/slow. Dynamically reduce oversubscribed transmit bandwidth as required via “throttling.”	✓

Source: Tolly, October 2025

Table 1



than 50% of wire speed until the congestion cleared.

Once the congestion cleared, the Marvell QLogic HBA automatically and gradually increased the traffic flow back to its original rate. Once the traffic returned to its original rate, the traffic stream was moved back to the "normal" virtual lane. Again, this was confirmed via the OS.

DIRL

Additionally, the Connectrix MDS FC director offers Dynamic Ingress Rate Limiting as a method to mitigate congestion automatically without requiring any software or configuration on the HBA. This provides an additional option for legacy environments. Figure 3 on page 6 provides an overview of this technology.

Test Setup & Methodology

Most elements were discussed in the Test Results section and will not be repeated here. This section will provide additional information on the setup and execution for test cases as appropriate. Solutions under test and configuration details can be found in Tables 2-5 on Page 7.

Test Traffic Generation

Flexible IO tester, or FIO, is an open-source traffic generation tool. FIO was used to generate traffic for the suite of tests. The bandwidth demonstration, interoperability, and resilience tests did not have specific traffic requirements. Resilience tests only required traffic to be traversing the elements under test.

The following is a test script used for general traffic. The specifics of the traffic are generally

not important. For congestion tests, the traffic should be "WRITE IO" from the initiator. FIO generates traffic and is set to run for the duration of the test and be cancelled manually by the test engineer once the test completes. Congestion test FIO command:

```
fio --name=test --readwrite=rw --rwmixwrite=100 --
invalidate=1 --end_fsync=0 --group_reporting --
direct=1 --size=1G --time_based --runtime=600 --
ioengine=libaio --norandommap --randrepeat=0 --
thread --exitall --zero_buffers --filename=/dev/disk/
by-path/
fc-0x2100f4c7aaa09f3a-0x50000972100fb00b-
lun-0 --bs=1M --continue_on_error=all --
iodepth=44 --numjobs=20 --
cpus_allowed_policy=split.
```

Switch Fabric Resilience

To test the director fabric resilience, it was necessary to ensure that the path between the host system and the storage array had to traverse the dual port channel, inter-switch links (ISL).

To force this, engineers disabled the initiator's second link to "Director B" and, similarly, disabled the storage array's link to "Director A." Thus, the FIO traffic could only reach the storage array by entering "Director A" and then crossing the ISL before exiting "Director B" into the storage array.

Virtual Lanes & Throttling

As noted, virtual lanes is a collaborative feature between the Marvell QLogic HBA and the FC director fabric. Director configuration consisted of just two commands: 1) feature fpm, and 2) system fc flow-control er_rdy logical-type all.

Similarly, the configuration on the HBA was equally straightforward and enabled both VL and throttling support. Those features can be used separately or in conjunction with each other. The driver was loaded with the following command: modprobe qla2xxx ql2xvirtuallane=1 ql2x_scmr_profile=3. This enabled VL support. The final parameter enabled aggressive throttling.

Dell Technologies,
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Dell PowerMax 64G
Enterprise Storage
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Additional Features

While beyond the scope of the current test project, the following are additional features & functions of the integrated solution:

Security

Dell Connectrix MDS

Dell Connectrix MDS directors provide comprehensive security capabilities including wire-speed, end-to-end frame encryption, silicon-based anti-counterfeit verification with secure boot processes, and line-rate port access control lists. The directors support hardware-isolated Virtual SAN domains with secure inter-VSAN routing capabilities, ensuring that sensitive data remains protected throughout the fabric infrastructure.

Marvell QLogic

In addition to CNSA-strength silicon "root of trust" for secure host boot, Marvell QLogic HBAs support comprehensive Encrypted Data in Flight (EDIF) that seamlessly and transparently protects FC SAN connections between servers and storage. This encryption operates at wire speed without impacting performance and integrates seamlessly with Cisco fabric security features.

Deep Analytics

Marvell QLogic HBAs offer comprehensive statistics including per-port performance metrics, error counters, and Virtual Lane utilization data that integrate with server management tools for end-to-end visibility. Dell PowerMax arrays contribute machine learning-based analytics for predictive failure analysis and capacity trending, creating a comprehensive monitoring ecosystem across the entire storage infrastructure stack. Dell Connectrix MDS directors provide detailed analytics including congestion heat-maps, credit-loss counters, and historical performance trending that enable proactive management of storage network performance. See Figure 4 on Page 6 for additional information on Cisco SAN analytics.

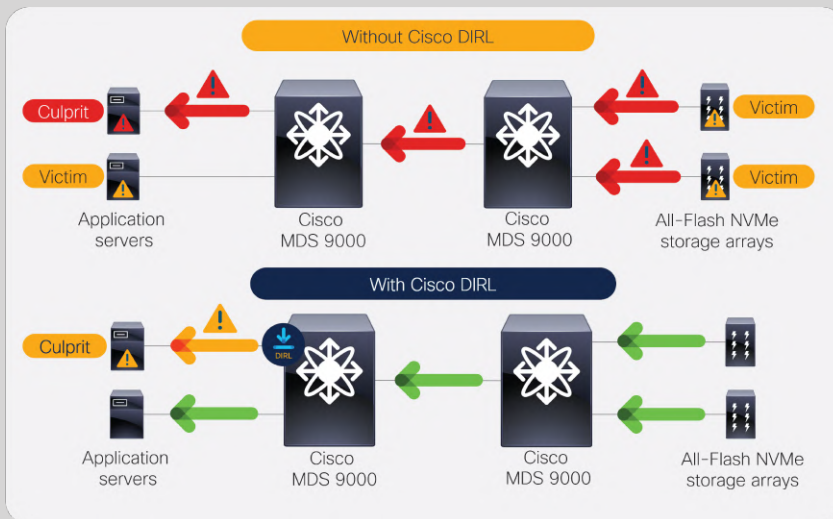
Source: Dell, Cisco Systems, & Marvell Tech.

Cisco Dynamic Ingress Rate Limiting (DIRL) Solution

Cisco Dynamic Ingress Rate Limiting (DIRL) is an innovative technology to bridge the performance gaps between the newer ultra-fast All-Flash NVMe storage Arrays (AFAs) and slower application servers. DIRL prevents the spreading of congestion caused by performance issues or slow-drain conditions in a Storage Area Network (SAN).

Benefits of DIRL

- End-device independent – Upgrading of end-devices is not needed.
- Adaptive – DIRL dynamically adjusts as per the traffic profile of the host.
- Affordable – No additional license is needed.
- Easy adoption – DIRL is available on the Cisco MDS 9000 Series Multilayer Switches after a software-only upgrade.
- No side effects – The rate-limiting is applied only to the congested host. Other non-congested hosts and storage ports are not impacted.
- Topology independent – DIRL works in edge-core, edge-core-edge, or collapsed core (single switch fabric) topologies.



Source: Cisco Systems

Figure 3

Cisco FC Switch SAN Analytics

Dell Connectrix MDS switches and directors, manufactured by Cisco, provide the fabric of the SAN and, thus, handle all traffic between servers and storage. The director is architected to inspect traffic using built-in taps, calculate metrics from frame headers, and export that data to external receivers via SAN Telemetry Streaming (STS). That information feeds the Nexus dashboard to help identify, isolate, and resolve issues that can be contributing to a slowdown of storage access and help meet and exceed user service level agreements.

NVMe and SCSI I/O Visibility Using SAN Analytics

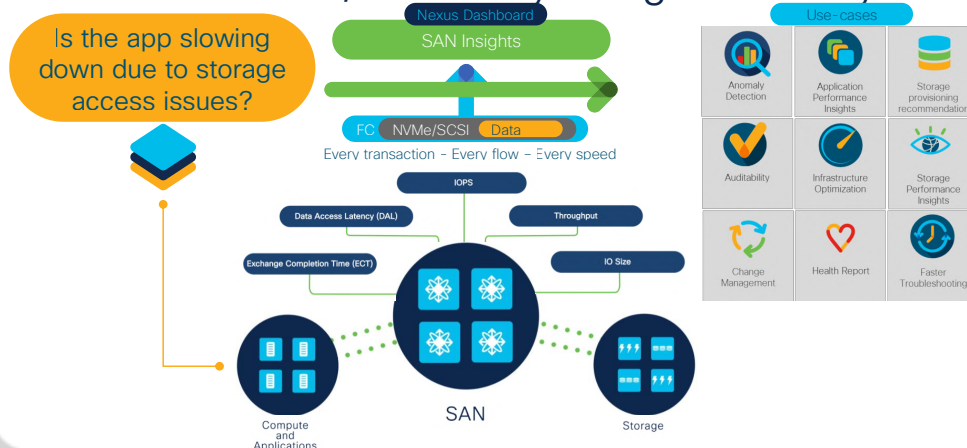


Figure 4



Test Configuration Summary

Dell 17th Generation Server Configuration

Vendor/System	Dell PowerEdge R760 (1RU)
CPU	2x Intel Xeon 6710E, model 175 stepping 3, 2400 MT/s, 64 cores each
Number of CPUs	128 processors (2x 64 cores)
Memory (RAM)	512 GB
OS	OS: RHEL 9.6 Kernel: 5.14.0-570.49.1.el9_6.x86_64
Kernel Settings	Multipath enabled with default settings

Table 2

Storage Array Configuration

Vendor/Device	Dell PowerMax 8500
Software	PowerMax OS 10.2.0.1
Configuration Notes	2x 64GB FC ports, one connected to each of the two FC directors

Table 3

Server Host Bus Adapter(s)

Vendor/Device	Marvell QLogic
Product Name	Marvell QLogic 2872C 64G FC HBA (dual-port adapter)
Firmware	9.15.03
Drivers	QLA Driver: 10.02.14.00-k (June 2025 Dell/Channel release)
Settings	Virtual Lanes support enabled

Table 4

Network Fabric

Vendor/Device	2x Dell Connectrix MDS 9700 Enterprise Directors (64G) - Relevant connectivity modules shown MDS 9718 48 ports DS-X9748-3072K9 8/16/32/64 Gbps Advanced FC Module MDS 9710 48 ports DS-X9748-3072K9 8/16/32/64 Gbps Advanced FC Module
Software	NX-OS 9.4(3b)
Configuration Notes	Virtual Lanes capable.

Table 5

Source: Tolly, October 2025



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