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Evaluation of Emulex® Gen 7 Fibre Channel HBAs by Broadcom

Gen 7 Fibre Channel HBAs provide significantly lower latency and higher transaction rates than the previous generation of Fibre Channel.

Executive Summary

Data centers are undergoing a transformation with the emergence of all-flash arrays, faster media types and more efficient ways to access media, delivering record speeds and lower latencies to significantly improve application performance. Key innovations in server and storage technology driving the evolution include NVMe and NVMe over Fabrics (NVMe-oF). The latest storage networking standard, Gen 7 Fibre Channel provides the ideal combination of performance improvements plus features to support this data center transformation, while maintaining backward compatibility with existing Fibre Channel infrastructure.

Broadcom has released Emulex® Gen 7 32GFC HBAs with 64GFC upgrade kits, enabling data centers to take advantage of advanced 32GFC features today, with the ability to upgrade to 64GFC when optics kits are available.

Demartek, owned by Principled Technologies, observed tests run with the newest Emulex Gen 7 LPe35000-series Host Bus Adapters (HBAs) by Broadcom to determine its latency performance advantages compared to its Gen 6 predecessor.

Demartek also observed performance tests with an Oracle Database comparing the Emulex LPe35000-series against the QLogic QLE2742-series.

In all tests we observed significant performance advantages with the Emulex LPe35000-series HBAs, along with unique feature enhancements.

Key Findings and Conclusions

> *Latency:* We observed **67% lower latency** compared to Gen 6 Fibre Channel HBAs.

> *IOPS Totals:* We observed **more than 5 million IOPS** with synthetic storage workloads- over 5x more than the QLogic 32GFC HBAs.

> *Test results (OLTP):* We observed **55% faster** Oracle 12c OLTP performance vs. the QLogic 32GFC HBAs.

> *Trunking:* Supports up to *128GFC on a single port* by aggregating multiple physical ports to form a single, logical, extremely high-bandwidth port.

> *Enhanced security with silicon root of trust:* Checks for authentic firmware every time the system is booted & before installing any new firmware.

Gen 7 Fibre Channel Overview

Gen 7 Fibre Channel provides several new features for modern data centers including:

> ***Fastest Single-Lane Networking Speed Currently Available:*** Support for the FC-PI-7 standard with Fibre Channel speeds up to 64GFC, which represents real world storage performance of up to 12,800 MB/s full duplex over a single lane serial SFP+ cable interface.

> ***NVMe over Fibre Channel:*** NVMe over Fibre Channel (NVMe/FC) brings predictable lossless performance of NVMe over Fabrics to the enterprise-level robustness that users have come to expect of Fibre Channel Storage Area Networks (SANs). Gen 7 Fibre Channel will benefit from the maturity of the second generation of the T11 FC-NVMe standard that brings enhanced "Sequence-Level" error recovery.

> ***Automatic Buffer Credit Recovery:*** Maintains maximum performance between ports under marginal link conditions. New enhancements to the already robust lossless network protocol include the ability to maintain the level of Buffer-to-Buffer credits automatically between Fibre Channel port connections.

> ***VM Awareness:*** Transport Virtual Machine (VM) identity information across the storage network to give SAN administrators better insight into VM application health and performance.

> ***Automation – Dev Ops:*** New Fibre Channel management constructs to facilitate orchestrated management and automation. New SAN management concepts such as target driven zoning and peer zones.

> ***Link Degrade Signaling:*** New standard for 64GFC optics that upon detecting a degraded link signal will inform the linked port of the detected degraded signal resulting in error reporting and potential recovery.

Emulex Gen 7 HBAs Overview

The Emulex LPe35000-series models include the dual-port LPe35002-M2 (the most popular configuration), single-port LPe35000-M2, and quad-port LPe35004-M2.

Figure 1: Emulex LPe35002, LPe35000, LPe35004

All models support 32GFC out of the box, with upgradeable 64GFC optics providing up to 64GFC throughput per port.

Broadcom has developed a number of new performance, operational efficiency and security enhancements including the set of enhancements described below.

Performance Enhancements

> *Fast path design:* Fast path provides full hardware acceleration for Emulex's Dynamic Multi-core architecture. Fast path processes IO requests in hardware in most instances with firmware only handling the exceptions. The result is significantly reduced latency performance.

> *Trunking:* A concept very similar to what is known in Ethernet as port aggregation. Trunking aggregates multiple physical ports to form a single, logical, extremely high-bandwidth port of up to 128GFC. The trunked port is ideal for high bandwidth applications including VM migration and data warehousing, as well as being a great tool for resolving congestion issues. Emulex Trunking works on any supported operating system and it can dynamically link and un-link, adjusting for times when it's needed such as backups. In a scenario where a link fails, the trunk will keep working, uninterrupted.

> *NVMe/FC:* Gen 7 Fibre Channel supports the mature, second generation T11 FC-NVMe standard, readying data centers for upcoming end-to-end NVMe deployments.

> *PCIe 4.0 capable:* Supports 2x bandwidth compared to PCIe 3.0.

Operational Efficiency Enhancements

> *Eliminate re-boots:* No re-boots are required for firmware updates, queue depth changes and optics changes.

> *Upgradeable:* Upgradeable to 64GFC with hot plug optic kits when kits become available.

> *End-to-end management:* Supports Brocade® Fabric Vision® features from the switch to the end-points (Emulex HBAs).

> *Dynamic port isolation:* Full error diagnosis and resolution capability without impacting traffic on any other port on the HBA.

Security Enhancements

> *Silicon root of trust:* Firmware authentication is embedded into the hardware, providing improved security against malicious firmware attacks. Firmware is authenticated every time the system is booted and before installing any new firmware.

Latency Performance Tests

Emulex Gen 7 HBAs were designed to address the revolution of low storage communication latency in modern NVMe datacenters. Broadcom set about achieving this goal through the fast path hardware architecture design that reduces average hardware latency to one third of the latency seen in the previous generation Gen 6 HBA. This dramatic reduction in latency impacts every frame that moves from the SAN to host PCIe bus in either direction as it passes through the HBA. Consistent low latency is fundamental to realizing application performance improvements and compliments new advancements such as PCIe 4.0, all-flash storage arrays and emerging NVMe over Fabrics networks.

To measure Gen 7 HBAs latency improvements, we precisely instrumented the two important interfaces of the HBA: the Fibre Channel port as it connects to the SAN, and the PCI Express interface of the host computer. See figure 2. We used two protocol logic analyzers on either connection and synchronized the clocks to ensure that both analyzers measured the events using accurately coordinated timing.

We then captured the time from when a Fibre Channel frame is received at the HBA FC port, inside the HBA the frame is then de-serialized, CRC checked, context registration updated, host memory destination determined then converted to the PCI Express protocol. The time was then measured again as the communication entered the host PCI Express port, the delta of the two timings determined the HBA hardware latency. See figure 3. The Gen 6 HBA latency was measured at 4.636µs, and the Gen 7 HBA latency was measured at 1.495µs –a 67% reduction.
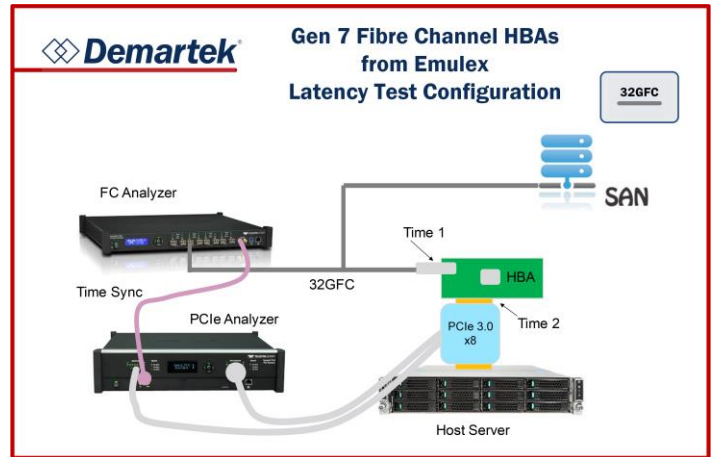

Figure 2: Latency Test Configuration

	Emulex Gen 7 HBA LPe35002 (@32GFC)	Emulex Gen 6 HBA LPe32002 (@32GFC)
HBA Hardware Latency (delta: FC to PCIe latency)	**1.495µs**	**4.636µs**
Percentage Improvement	**67%**	

Figure 3: Latency Test Results

Synthetic IOPS Test Results

Emulex Gen 7 FC HBAs were designed to improve I/O's per second (IOPS), especially at the smaller block sizes. Running synthetic I/O workloads, we observed *more than 5 million IOPS across two ports* in both the read and write tests, with more than 6 million IOPS in the read tests across two ports. Compared to the QLogic HBA, the Emulex Gen 7 HBA delivered *over 5X more IOPS*.

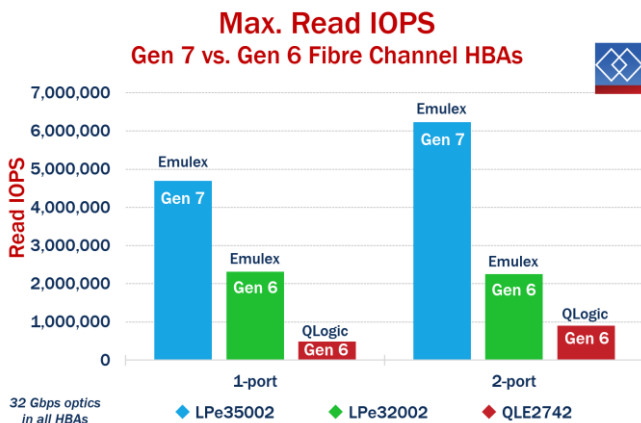32GFC transceivers (optics) were used for all the FC HBAs in this test.

Figure 4: Read IOPs- Emulex Gen 7 vs. Gen 6 HBAs
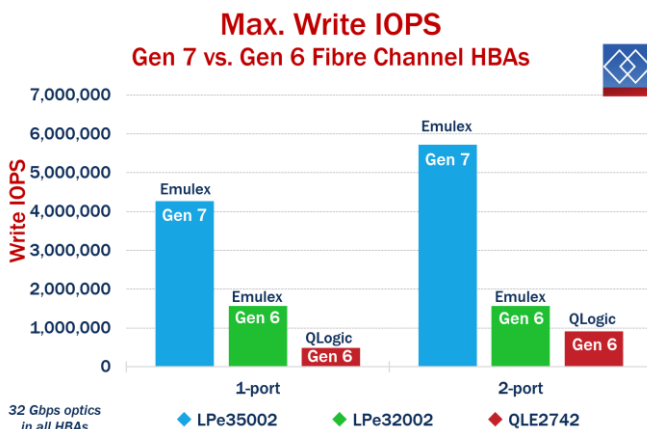
Figure 5: Write IOPS- Emulex Gen 7 vs. Gen 6 HBAs

Application Results: Oracle Database 12c OLTP

We observed that the Emulex Gen 7 latency and IOPs performance has improved considerably in instrumented synthetic benchmarks running isolated IO, but does this translate into real world benefits for a typical data center configuration?

To test this, we compared the performance of the HBAs in an Oracle Database 12c server with the data stored on a NetApp AFF A800 all-flash array. HammerDB was used to simulate an OLTP client load of 128 virtual SQL transaction users to a 500GB TPC-C- like dataset representing 5000 warehouses. We sized the server memory to simulate a typical customer configuration that would achieve a 1:10 memory to OLTP dataset ratio, meaning that many of the database transactions would require high IO request rates of the NetApp all-flash array.

The Oracle 12c OLTP workload, running with HammerDB, achieved *55% higher transactions per minute (TPM) with the Emulex Gen 7 FC HBA than with the available QLogic FC HBA.* Both used 32GFC optics. Simply changing the HBA to the Emulex Gen 7 model proved that we were able to extract considerably more application value out of an existing server and storage investment. This serves as an excellent real-world example of the performance benefits of the Emulex Gen 7 HBA.
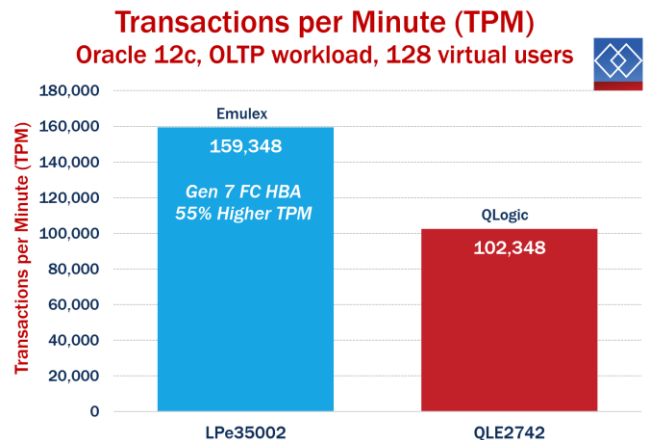

Figure 6: Oracle Database 12c TPM performance-Emulex 32GFC vs. QLogic 32GFC

Summary and Conclusion

Broadcom has demonstrated solid engineering with the design of their latest Emulex Gen 7 FC HBAs, delivering impressive IOPS performance and reduced latency compared to previous generations of FC HBAs as these tests revealed.

The Emulex Gen 7 FC HBAs achieved more than 5 million IOPS in the synthetic read and write tests, 67% lower latency than their previous generation FC HBA, and 55% higher database transactions per minute than the currently available competitive FC HBA.

If you are deploying 32GFC switches and high-speed storage devices such as all-flash arrays and NVMe devices, you should consider Emulex Gen 7 32GFC HBAs over other 32GFC HBAs to reap the performance, operational efficiency, security benefits.

The adapters are broadly available from Dell and Emulex channel partners.

The most current version of this report is available at
https://demartek.principledtechnologies.com/Demartek_Broadcom_Emulex_Gen7_Fibre_Channel_HBA_Evaluation_2019-02.html
on the Demartek website.