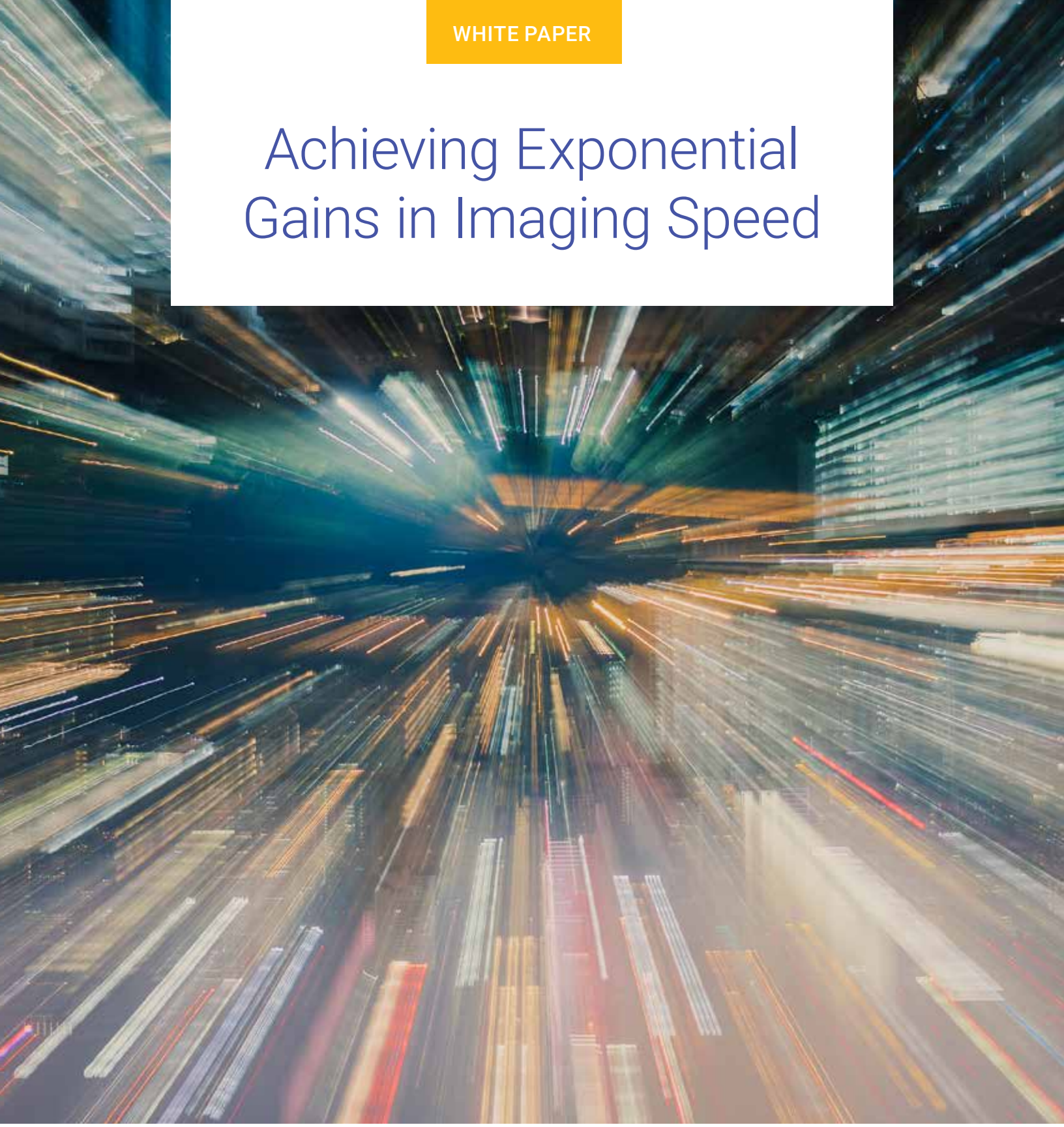
WHITE PAPER

Achieving Exponential Gains in Imaging Speed



A Dicom Systems and Pure Storage White Paper

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Dicom Systems and Pure Storage conducted testing to evaluate if high-performance data storage affects medical image transmission latency and transfer speed. The testing focused on the routing functionality of the Dicom Systems Unifier enterprise imaging platform.

We tested various workflow functions including but not limited to Unifier DICOM routing and tag morphing, supported by Pure Storage® hardware. Our goal was to confirm if transmission time and transfer speeds correlated with storage performance. Measurements included large, regular, and small DICOM studies. We tested a maximum throughput of 1,280 megabytes (MB) and assessed I/O performance and latency.

Conclusions

When the Unifier platform runs on Pure Storage hardware, the combined solution has the capability to migrate more than 800,000 imaging studies per day.

800,000

Image studies migrated per day

An average hospital produces 600,000 exams annually, meaning 125% of an average hospital's annual imaging volume can be moved in a single day. Unifier workflow functionalities, used together with high-performance storage, were free of bottlenecks related to processing, routing, transformation, and the output of AI algorithms for imaging workflows.

Why We Conducted This Test

Accelerating the speed of imaging studies is strategically important for healthcare organizations, but problems with imaging transmission speed can be difficult to diagnose and correct.

Healthcare organizations may experience bottlenecks related to processing, routing, transformation, and the output of artificial intelligence (AI) algorithms for imaging workflows. There are many variables involved, including complex imaging workflows, disparate systems running in different environments, lack of a modern enterprise imaging platform, and/or use of data storage that's not sufficient for high volume enterprise imaging.

In healthcare organizations, network capacity is a major variable affecting imaging transmission rate. However, our research demonstrates that healthcare organizations can significantly increase their imaging transmission speeds by pairing a modern enterprise imaging platform with high-performance storage.

STATISTICAL SUMMARY

Optimizing the Unifier DICOM router for use on Pure Storage accelerated speeds for image routing to:

- **137 million images per day**
- **5.7 million images per hour**
- **93,220 images per minute**
- **1,587 images per second**

This research demonstrates healthcare organizations can improve transfer speed with minimal overhead, even when peak numbers of studies are transmitted. Organizations can improve transfer speed by optimizing an imaging platform to take advantage of high-performance storage and hardware.

UNIFIER PLATFORM ROUTING FUNCTIONALITY

The Unifier platform is a robust, proven, interoperable enterprise imaging platform that ensures medical images and studies are integrated and always accessible. This highly configurable platform features:

SSL-based DICOM and HL7 integration tools to connect image transfer workflows and new sites, load balancing for optimized imaging traffic, vendor-neutral archiving to integrate all imaging data, de-identification of PHI compliant with HIPAA Safe Harbor standards, intelligent routing, and optimized radiology and teleradiology workflows on-premise or in the cloud.

Methodology and Detailed Results

We tested the direct correlation of image transfer throughput increase with the use of the Unifier platform's routing functionality and Pure Storage. The research addressed varying image sizes, configurations, workflow scenarios, and hardware resource allocation. For this test, Unifier platform's standard storage was utilized, which is a high-performance, working tier.

Types of studies tested:

- Study with large images (e.g. Mammography images, or large MPEGs)
- ES_MPEG - 100 megabytes (MB) per image, 100 images per study. Size of one study - 10,000 MB
- Study with regular images (e.g CT, CTA, PET/CT images)
- CT - 515 kilobytes (KB) per image, 2,000 images per study. Size of one study - 1,000 MB
- Study with small images (e.g. CR/DR, or even MR images)
- SR (artificial) - 1 KB per image, 10,000 images (img) per study. Size of one study - 10 MB

Summary of routing tests:

Size of objects:	FlashArray™ //X50 - SAN	
Large	1,280 MB	13 img
Regular	946 MB	1,861 img
Small	1.56 MB	1,881 img

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Pure Storage FlashArray and FlashBlade® uniquely support the initiatives driving today's enterprise imaging departments. While the testing in this white paper involved FlashArray//X, other products include:

FlashArray//C with Purity 6.1 is enterprise-ready and provides 99.9999% availability, with healthcare customers experiencing up to a 50 percent reduction in read latency.

FlashBlade gives radiologists and technicians increased productivity with low latency that ingests and retrieves images up to four times faster than competitors, while optimized for AI workloads.

Results:

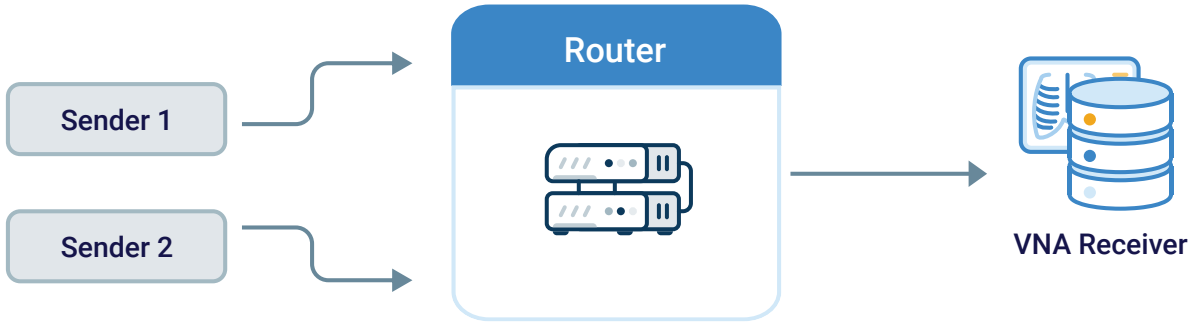
The DICOM router's performance scaled with the system resources, even when throughput was maxed to 1,280 MB. When used onsite with Pure with throughput of 1,280 MB, the DICOM router ran through a study mix as follows:

- **15% large images**
- **70% regular images**
- **15% small images**

Based on the study mix, this is approximately 1,587 images per second (13x0.15+1861*0.7+1881*0.15), 95,220 images per minute, 5.7 million images per hour and 137 million images per day. The rate of 1,587 images per second is equivalent to about eight imaging studies per second, which would be a fast, efficient rate during peak demand for imaging at an average healthcare organization.

If a conservative estimate is applied for an average healthcare organization, and assuming an overall average of 170 images per study, a total of 806,000 studies per day would be routed. The key factor for performance scalability is storage space and configuration, network and compute. When we ran the various configuration scenarios, the Pure Storage solution required no tuning and was an off-the-shelf deployment.

Routing workflow diagram



Test 1.1: Routing / FlashArray//X50 SAN / large images

Pure Storage and Dicom Systems conducted a 10 hour test involving routing large images with the Unifier DICOM router, supported by Pure Storage hardware.

We configured the VNA receiver as a mock receiver. Exams were processed but not retrievable, minimizing delays. PostgreSQL DB and storage were separately located on the FlashArray//X50 (Storage Attached Network). Storage had FIFO mode enabled, 1 terabyte (TB) quota set, and used the Unifier platform's standard storage tier.

- We used Both Sender 1 and Sender 2 for "feeding" the routing function, utilizing both 10 gigabits per second (Gbps) and network interfaces. The Unifier DICOM router sent studies to the VNA using 10 Gbps network cards. The routing function had four network cards installed to increase network throughput: two were for input and two for output.
- Both senders used a similar pack of specially prepared studies, with a maximum of 10 threads for sending and a maximum of 50 threads for routing.
- The routing function had 2 TB storage with the FlashArray//X50 (SAN), which was FIFO enabled, standard storage, with separate storage for index files.

SUMMARY OF RESULTS

1,280 MB | 13 images

Max routing speed achieved was 1,280 MB and 13 images per second.

Detailed Summary

Routing speed is limited mostly by network card and storage speed. Even when four 10 Gbps network cards are used, the back end might have some limitations for utilizing the full throughput Storage utilization ~78%. CPU utilization ~47%. Network utilization ~40% of total throughput. The storage showed a high queue size >22.

- Minimum hardware requirements for this type of workflow: 12 CPU cores, 16 GB RAM (32 GB recommended), 10 Gbps network card, and fast storage. Two TB of storage can keep about 30 minutes of cache.
- A simple transformation rule was applied during separate testing (tag morphing) and the router's performance wasn't affected in any way.

+ **Further details on Hardware Specifications are in Appendix A. Details on Test 1.1 are in Appendix B.**

Test 1.2: Routing / FlashArray//X50 SAN / regular images

This test's purpose was to measure the performance of the Unifier DICOM router's function with regular images. The test lasted 10 hours.

- We configured the VNA receiver as a mock receiver. We removed studies as soon as they were received, minimizing delays. PostgreSQL DB and storage were located on separate partitions on a single FlashArray//X50 (SAN). Storage had FIFO mode enabled, 1 TB quota set, and used the Unifier platform's standard storage tier.
- We used both Sender 1 and Sender 2 to feed the routing function, utilizing both 10 Gbps and network interfaces The routing function sent studies to VNA using a 10 Gbps network card. Only two 10 Gbps network cards were installed on the routing function during this test.
- Both senders used a similar pack of specially prepared studies, with a maximum of 10 threads for sending and a maximum of 60 threads for routing.
- The routing function had three 2 TB storage FlashArray//X50 (SAN), FIFO enabled, with the Unifier platform's standard storage and separate storage for DB, DICOM, and index files.

SUMMARY OF RESULTS

946 MB | 1,861 images

Max routing speed - 946 MB per second, 1,861 images per second

Detailed Summary

The routing speed was limited mostly by the network speed and CPU utilization. Storage utilization was about 50% (queue size ~5) for DICOM files. CPU utilization is about 70%. Max network utilization ~56%.

The minimum hardware requirements for this type of workflow were: 16 CPU cores, 16 GB RAM (32 GB recommended), 10 Gbps network card, and fast storage. Two TB of storage kept about 35 minutes of cache. Performance bottleneck is the number of CPU cores and network speed.

+ **Further details on Test 1.2 are included in Appendix C.**

Test 1.3: Routing /FlashArray//X50 SAN / small images

This 10 hour test measured the DICOM router's performance with small images when used in combination with Pure Storage hardware.

We configured the VNA receiver as a mock receiver and removed studies as soon as they were received, minimizing delays. PostgreSQL DB, index files, and DICOM files were located on separate storage - FlashArray//X50 (SAN). The storage had FIFO mode enabled, 1 TB quota set, and used the Unifier platform's standard storage tier.

We used both Sender 1 and Sender 2 to feed the routing function, utilizing both 10 Gbps network interfaces. The routing function sent studies to VNA using a 10 Gbps network card. Only two 10 Gbps network cards were installed on the routing function

- Both senders used a similar pack of specially prepared studies, with a maximum of 10 threads for sending and a maximum of 20 threads for routing.
- The routing function had three 2 TB storages: FlashArray//X50 (SAN), FIFO enabled, and the Unifier platform's standard storage tier. We used separate storage for the DB, DICOM, and index files.

SUMMARY OF RESULTS

1.56 MB | 1,881 images

Max routing speed was 1.56 MB per second, 1,881 images/sec.

Detailed Summary

Routing speed was limited mostly by RAM speed. Storage utilization was about 40% (queue size ~1.5). CPU utilization was about 25%. Network utilization <1%.

This workflow required the following minimum hardware requirements: 12 CPU cores, 48 GB RAM (64 GB recommended), 10 Gbps network card, and fast storage.

+ **Further details on Test 1.3 are included in Appendix D.**

For more information call
415.684.8790 or visit **dcmsys.com**

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