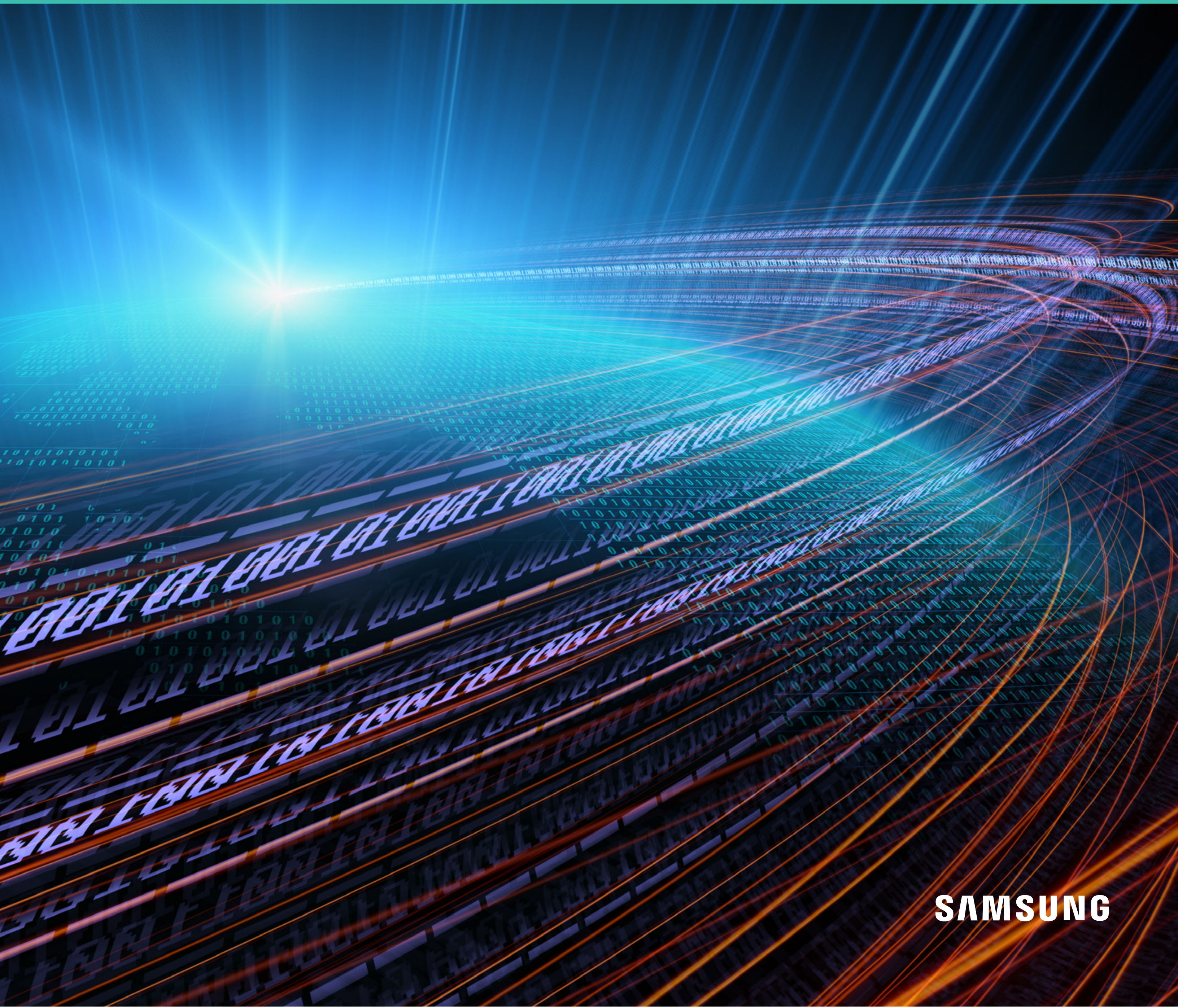
Maximizing Data Center and Enterprise Storage Efficiency

Enterprise and data center customers can leverage AutoStream to achieve higher application throughput and reduced latency, with negligible organizational and infrastructure impact, using Multi-stream SSDs

A Technology Brief by Samsung Memory Solutions Lab



Maximizing Data Center and Enterprise Storage Efficiency

Summary

AutoStream, a new Samsung Memory Solutions Lab innovation, enables systems to increase Multi-stream SSD performance. Unlike a traditional Multi-stream approach that demands significant, complex engineering analysis and intricate application modifications, AutoStream non-invasively accelerates storage access in a dramatic fashion. This has the potential of significantly improving data center and enterprise applications development investments, while maximizing existing engineering resources.

Background

High-performance, high-density SSDs increasingly satisfy the growing needs of data centers and enterprise for much improved application storage. However, NAND-based SSD out-of-place updates, limited P/E (Program/Erase) cycles, and *garbage collection* (GC) overhead continue to present critical SSD performance challenges. This is because NAND-based SSDs use a *log structure* to append new host data-writes to an associated *log tail*.

Moreover, with traditional SSDs, all host write-request data are written to device media in *arrival-order* regardless of data properties such as *temperature* (data-validity lifetime). Here, *higher* temperatures indicate data values update more frequently (have a shorter lifetime). These factors inevitably result in high GC overhead because GC erase block victims usually have a mixture of valid and invalid data due to different lifetimes of the data they store. This requires the device to copy valid data to a new erase block before erasing the original erase block, thereby impacting device performance.

Enterprise and data center customers can leverage AutoStream to fully utilize Multi-stream SSDs, such as the Samsung PM1725a and PM963 NVMe SSDs, as well as the PM1633 and PM1633a SAS SSDs to achieve higher application throughput and reduced latency, with negligible organizational and infrastructure impact.

PM1633/A

PM1725a

PM963

SAMSUNG

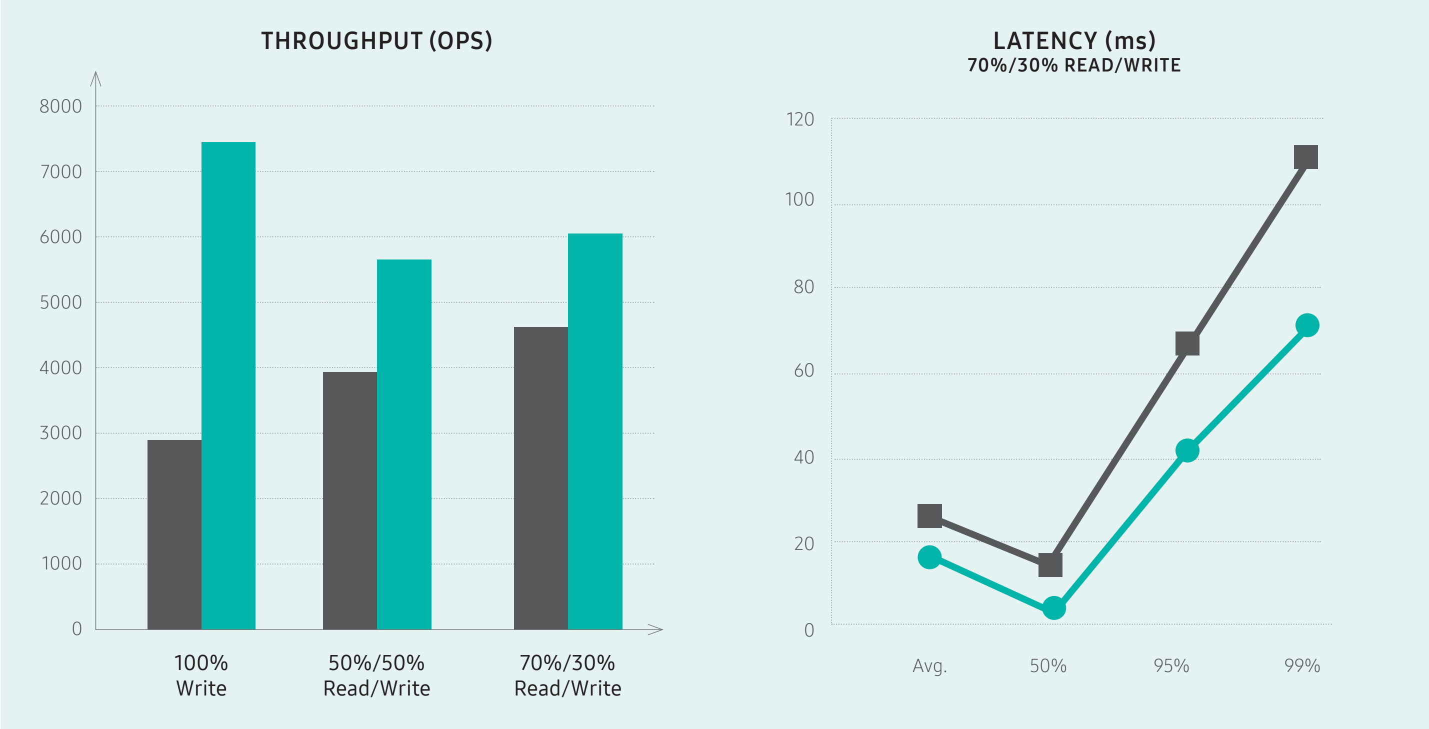
Multi-stream SSDs

Traditional SSDs have one log structure, one associated log append point, and one global *open erase block* to store incoming write data. *Multi-stream SSDs,* such as the PM1725a, PM963, PM1633, and PM1633a from Samsung maintain multiple log structures, each with their own log tail append point and unique *open erase block*. This multiplicity provides SSD *Flash Translation Layer* (FTL) firmware with the flexibility to direct data blocks having different characteristics to different log structures, and separates the arriving host data-write stream into *multiple streams.*

With Multi-stream SSDs, a FTL can store different temperature data using different streams. As a result, all stream-directed data in a given erase block tends to have a similar lifetime and becomes invalid together, therein improving throughput and lowering latency, as well as reducing GC overhead.

An example of the benefits of Multi-stream SSDs is illustrated in Figure 1, where Cassandra achieved up to 3x performance enhancement because of its Multi-stream capability.

Figure 1. Cassandra Performance with eight streams (*)



(*)Intel (R) Xeon (R) E5-2630 v3 @ 2.40GHz, 32 Logical Cores, 64GB Memory, Linux Ubuntu 16.04, Kernel v4.6.0-24 with Multi-stream patch, Samsung PM1633 12G SAS Multi-stream SSD, Cassandra 3.5.0 with Multi-stream patch, 1M records 16KB data size

Multi-stream SSDs (continued)

Multi-stream SSD technology is frequently used to tag each application write request with a *stream ID*. This passes the stream ID from the application to the file system and onto the Multi-stream device through an operating system *device data-write call*.

The Multi-stream device receives the host write-data and redirects that data to the corresponding active erase block associated with the stream ID arriving with the data. In summary, stream ID tagging gives application developers the capability to identify different types of data, as needed.

For example, by using different stream IDs, developers can write user data to one erase block and associated metadata to a different erase block. Unfortunately, this tagging approach usually requires application developers to have advance, detailed data temperature knowledge pertaining to:

- Application executions under all conditions
- The system I/O stack
- Device stream resource limitations (e.g., the number of streams that the device supports).

Moreover, existing applications must be modified to identify streams and tag stream IDs to data write requests. Note that poorly assigning stream IDs may defeat the purpose of Multi-stream, at worst resulting similar performance as a traditional SSD without Multi-stream support.

In theory, modifying applications to provide effective stream ID assignments is conceptually a straightforward process. However, in practice, application source code may not even exist for modification. Moreover, complex applications often produce surprisingly complex I/O activity. It follows that stream ID tagging usually requires complex analysis to be made by programmers who likely only have a partial understanding of the logic. Furthermore, application regression testing should be performed to ensure enterprise application stability and correctness.

AutoStream

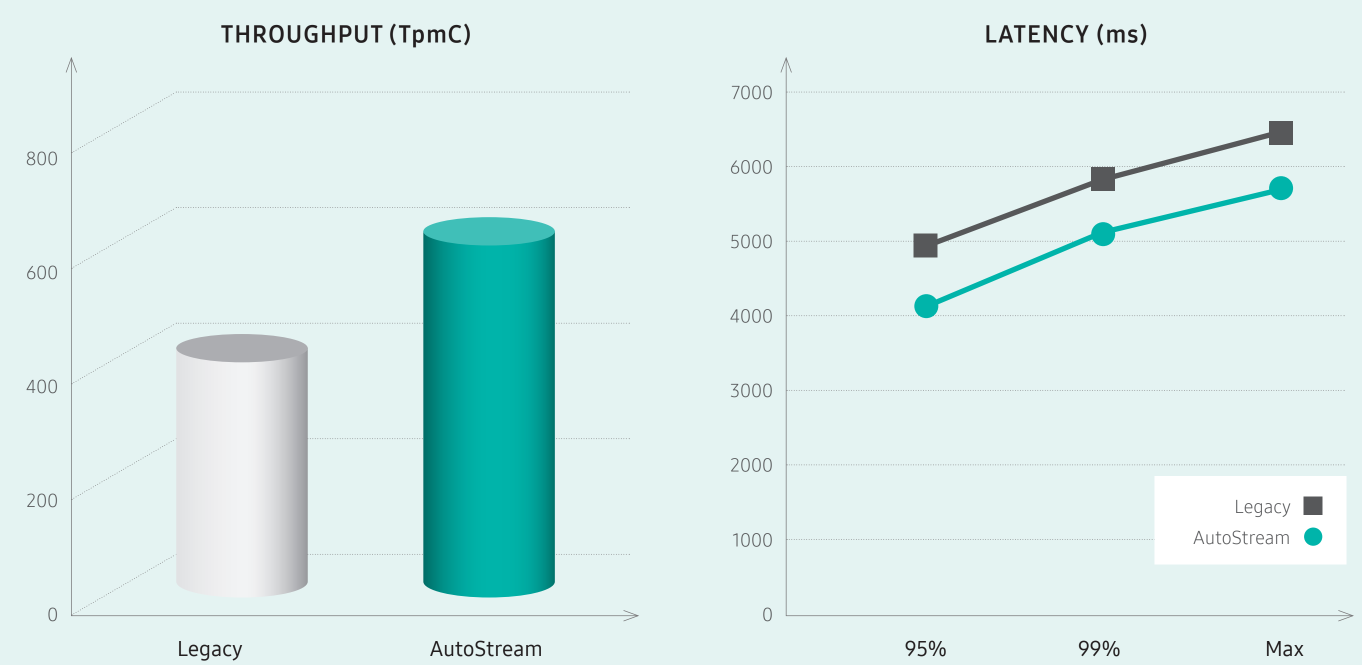
Analysis is even more complicated in data center environments supporting multiple Virtual Machines (VMs) and *containers* that access the same device. In these situations, it is necessary to coordinate stream ID assignments across different application development teams to prevent one application's streams from interfering with another's. This requires organizational coordination, in some instances across multiple time zones, continents, and even languages. Even worse, Multi-stream SSDs presently only support a limited number of streams. Hence, stream ID assignment contention is inevitable. Fortunately, AutoStream bypasses these challenges.

AutoStream is a Samsung Memory Solutions Lab innovation that performs Multi-stream tagging at the operating system *device driver* level. This means no application modifications are necessary to benefit from Multi-stream SSDs. AutoStream automatically detects data temperature at run time and assigns stream IDs without application involvement. Compared to existing workload detection mechanisms that only bifurcate host data writes into a small, limited number of groups (hot, cold and warm), AutoStream can differentiate data with enhanced granularity and dynamically distribute it to more or fewer streams depending on the number of streams a storage device supports.

Experimental results led by Samsung show that AutoStream achieves significant performance improvements compared to the legacy approach. The AutoStream tests used Samsung Multi-stream PM1725a NVMe SSDs with different applications, workloads and system configurations. The tests conclusively proved that data centers can use AutoStream in a manner that is transparent to applications, without applying any modifications to the application itself.

As shown in Figure 2, MySQL could achieve more than 40% throughput improvement and more than 15% latency reduction. Cassandra could achieve a latency reduction of up to 40% (99.9% latency) even though throughput enhancement is limited.

Figure 2.1. MySQL Performance with eight streams (**)



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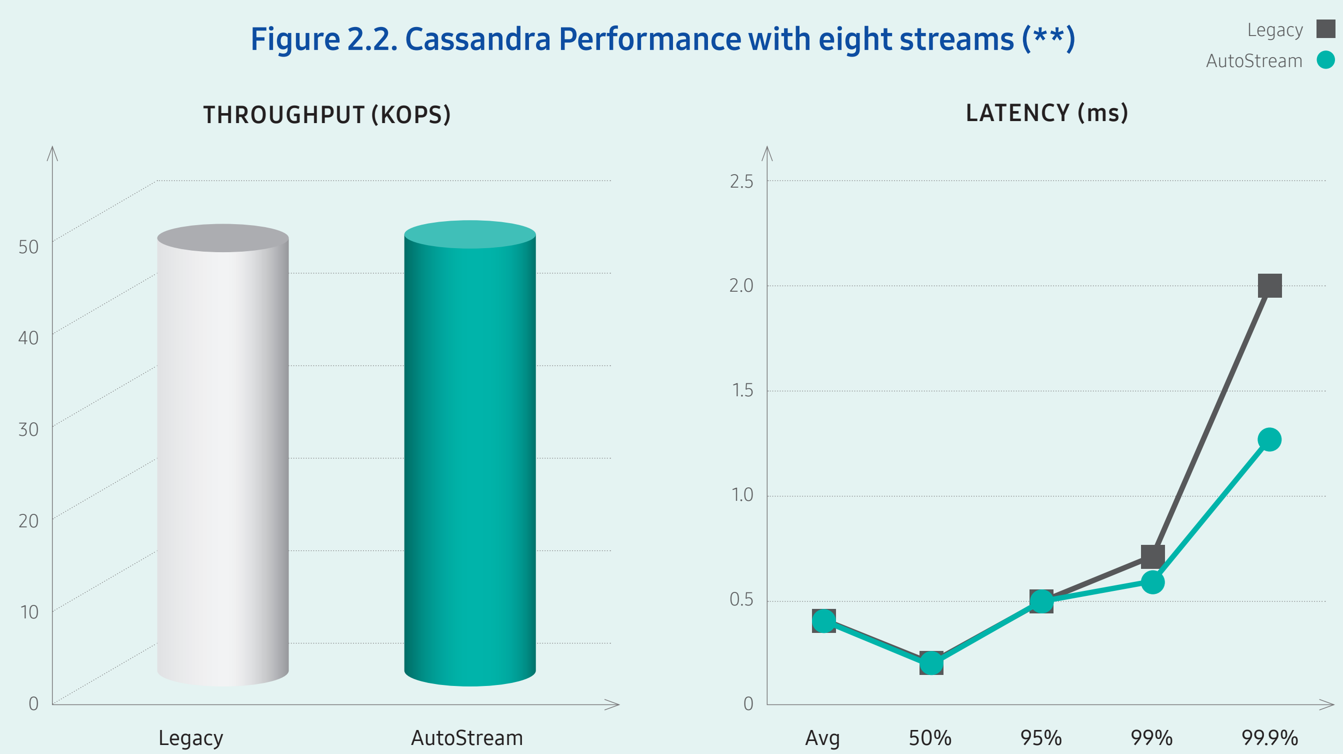
AutoStream (continued)

Figure 2.2. Cassandra Performance with eight streams (**)



(**)Intel (R) Xeon (R) E5-2630 v3 @ 2.40GHz, 32 Logical Cores, 64GB Memory, Linux Ubuntu 16.04, Kernel v4.6.0-24 with Multi-stream patch, Samsung PM1725a NVMe Multi-stream SSD, MySQL TPC-C 1600 warehouse, 60 connections, Cassandra 3.5.0 with Multi-stream patch, 200M records of 16KB data size, Read/Write 50/50% workload

For More Information

For performance details and more information on leveraging this methodology, please refer to the information below.

Multi-stream SSD Information:
http://www.samsung.com/semiconductor/insights/article/25465/multistream

Performance and Endurance Enhancements with Multi-stream SSDs on Apache Cassandra
http://www.samsung.com/us/labs/collateral/index.html#form-content

AutoStream Systor Conference Paper:
http://dl.acm.org/citation.cfm?id=3078469

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