

Silicon Motion's SM2270 SSD Controller

Enables Open Channel SSD Designs For Data Center Applications

Big data, video-on-demand, social networking and the rapid adoption of cloud computing in both consumer and enterprise applications are dramatically changing the requirements for large-scale data storage. Data center operators and Cloud Service Providers (CSPs) such as Amazon Web Services and Microsoft Azure are facing a new and demanding set of challenges: the need to continually scale up storage capacity, to respond to changing application requirements, and to optimize the efficiency and performance of an array of Solid State Disks (SSDs) - and all this while reducing the cost-per-gigabyte of storage in order to control their expenditure on infrastructure.

In response to these new requirements, the industry has developed the Open Channel architecture, providing a new model for the control and operation of individual SSD devices in data centers which serve multiple tenants and applications. The storage software engineers at CSPs and data centers have great expertise in managing and optimizing storage capacity. In their dynamic operating environment, it is essential to have a flexible platform for storage provision which supports a rapid response to new application requirements and which facilitates timely enablement of new features.

For similar reasons, the systems integrators which provide complete hardware/software solutions to enterprise customers also need a flexible platform for the rapid, cost-efficient development of customized storage systems.

The Open Channel model provides important benefits for all these users. It offers:

- **Flexibility** to optimize a storage array for specific workloads. In a multi-tenant environment, many different applications with different operational requirements run on shared physical storage devices. In the Open Channel architecture, the storage capacity of each individual SSD can be configured optimally for each application, and the configurations changed dynamically.
- **Rapid adoption of new SSD devices** based on the 3D and QLC NAND Flash technologies. Ultra-high density NAND Flash technology provides the lowest cost-per-gigabyte. The time required to qualify Open Channel-compliant SSDs is also shorter, reducing the cost of introducing new storage devices into data center infrastructure.
- **Vendor diversity** - when continually scaling up storage capacity, data center operators and CSPs want to be able to source new SSDs from multiple suppliers, giving them a stronger negotiating position and greater supply-chain flexibility. The Open Channel architecture simplifies the control technology on the SSD device side, and this supports the development of a bigger, more diverse ecosystem of SSD suppliers.

The Open Channel specification provides a new type of SSD architecture based on the familiar NVMe protocol for the interface between a host and an SSD. It enables the partitioning of functions, so that data placement, the main function of Flash Translation Layer (FTL) software, is executed on the host side, while media management - functions such as NAND Flash access and error correction - may be implemented in the SSD device (see Figure 1).

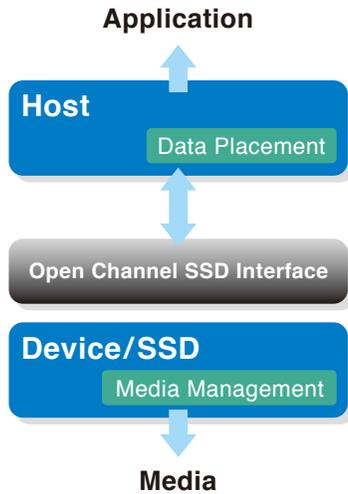


Fig. 1: the Open Channel architecture provides for partitioning of data placement and media management

In an Open Channel SSD, the parallel internal paths in the SSD are exposed to the host, so that the host can control the entire I/O channel right down to physical locations within an individual SSD device. This enables the host - which knows the requirements of the applications which it is running on an SSD device - to optimize data placement and maintain appropriate I/O isolation (see Figure 2). When the SSD's memory locations are exposed to the application software, the physical allocation of data can be arranged to provide for isolation of I/Os belonging to different applications, or to different tenants in a multi-tenant environment.

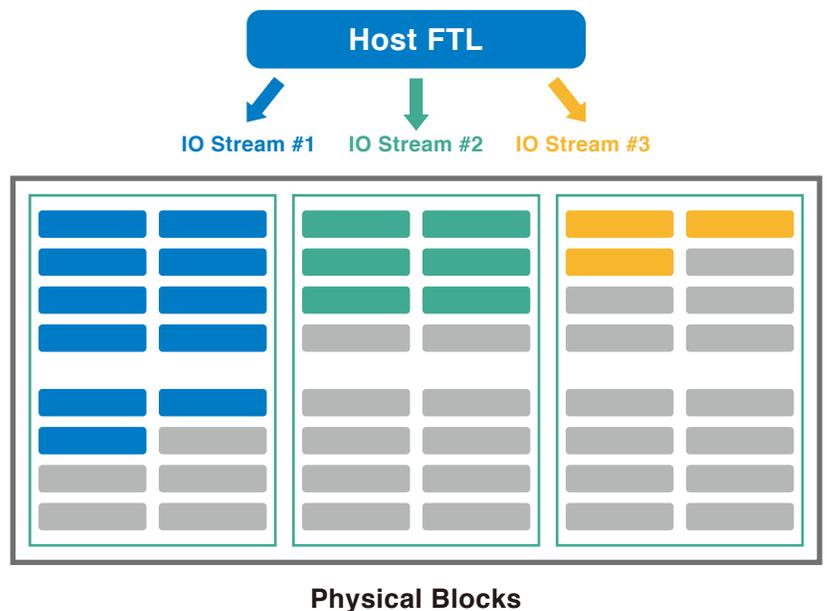


Fig. 2: when FTL is implemented on the host side, the host can maintain appropriate I/O isolation and optimize data placement

This eliminates the risk that one application's Read or Write operations could delay or interfere with another's. The result: reduced latency in data-transfer operations; and equally important, predictable latency (see Figure 3).

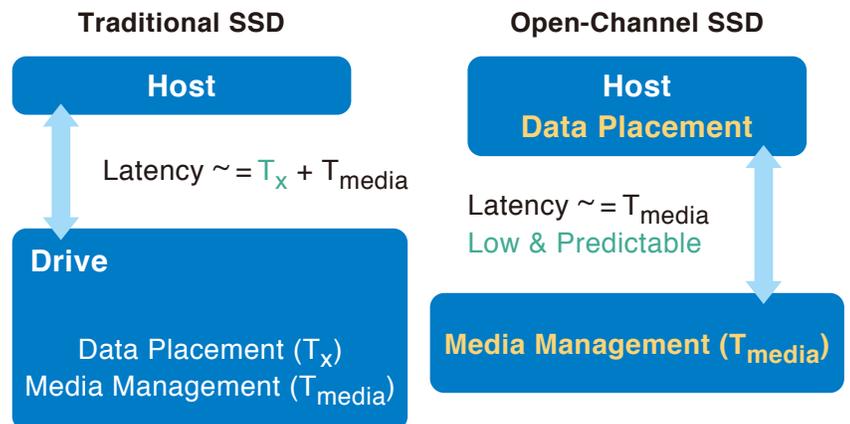


Fig. 3: in an Open Channel architecture, the SSD media's contribution to latency is transparent to the host and entirely predictable

T_x : uncertain

- command processing
- IO scheduling
- Garbage collection...

T_{media} : fixed by media

- Within a period of time

The partitioning of media management and data management functions between the device and the host also plays to the strengths of NAND Flash storage device manufacturers on the one hand, and data center software engineers on the other. SSD manufacturers maintain large teams of NAND Flash experts, people who have built up over many years an exhaustive knowledge of the behavior of NAND Flash, of the effects of operating temperature and other conditions, of the rate of degradation versus the number of Program/Erase cycles, and of the proper fault diagnosis and recovery operations.

Likewise, software development engineers at CSPs, data center operators and systems integrators can bring to bear their deep knowledge of applications to enable them to optimize data placement and I/O scheduling.

Important SSD attributes in an Open Channel environment

Following the introduction of the Open Channel specification, data center operators and cloud computing service providers have been evaluating the hardware options available for implementing Open Channel-compliant SSD designs. This has prompted the industry's leading suppliers of SSD controller solutions to announce the introduction of new products that include Open Channel support. Silicon Motion is the world's largest manufacturer of merchant SSD controllers by value and by number of production units. In August 2018, it announced at the Flash Memory Summit the introduction of the SM2270, a dual-mode SSD controller solution which enables operation either in normal NVMe mode or in a readily customizable Open Channel mode.

This customization capability is an essential feature of SSD devices for use in an Open Channel environment. The Open Channel v1.2 and v2.0 specifications have been ratified by the storage industry, but they are not today being implemented universally as a standard technology. Rather they provide a framework within which data centers,

CSPs and other large users of SSD storage implement their own system solution, often with a unique and proprietary interface between the host and SSD.

SSD controller solutions from Silicon Motion readily support this requirement for custom implementations of the Open Channel architecture.

This is because of the unique configuration of the ASIC and firmware at the heart of every Silicon Motion controller solution, including the SM2270. This provides for a broad range of customizations of an SSD design to meet the user's individual specifications. In particular, the SM2270 allows the user to specify:

- the interface command sets
- the partitioning of FTL jobs between the host and the SSD

There are two other crucial attributes required of the controller in an Open Channel SSD:

- Advanced media management for the latest generations of NAND Flash technology
- Data integrity technologies which perform comprehensive error detection and correction

Advanced media management

NAND Flash manufacturers have succeeded in refining the processes for manufacturing leading-edge 3D and QLC (Quad Layer Cell) NAND Flash memory chips. These NAND Flash ICs offer substantial density and cost-per-gigabyte advantages over earlier generations of NAND Flash. They do, however, require the application of technologies to balance the allocation of Write operations evenly across all physical storage locations, and to correct bit errors in Read and Write operations.

The technologies integrated into the SM2270 SSD controller solution are the industry's most effective for

prolonging reliable operation, and are proven in mission-critical industrial and embedded applications. Silicon Motion draws on more than two decades of experience in managing NAND Flash media. Silicon Motion's relationships with the world's leading manufacturers of NAND Flash silicon provide it with a unique level of insight into the characteristics of NAND Flash, right up to the newest 3D TLC and QLC generations of the technology.

This expertise is reflected in the advanced media management technologies implemented in Silicon Motion SSD controller solutions. These include Silicon Motion's NANDXtend™ technology, which incorporates machine learning error-recovery algorithms.

In addition, in the Open Channel architecture the SSD does not need to maintain the mapping table in DRAM because data management is performed by the host. The biggest components of the cost of an SSD are normally the NAND Flash array and the DRAM. By eliminating the DRAM and enabling the use of the lowest-cost-per-gigabyte, highest-density NAND Flash technologies, Silicon Motion helps SSD

manufacturers to deliver products which meet the most demanding capacity and cost specifications set by data centers, CSPs and systems integrators while supporting the industry's Open Channel initiative.

High data integrity

Several types of NAND errors can occur during NAND Flash access. Reliable operation of an Open Channel SSD requires the detection and correction of these errors.

An Open Channel SSD based on an SM2270 controller solution can provide an almost error-free data output, thanks to the implementation of advanced data integrity features in the controller. These include end-to-end data path protection, which applies ECC to buffer memory as well as to the primary NAND Flash memory array. This maintains the integrity of every bit of data as it is transmitted between the host and the

SSD, and between buffers and NAND Flash.

Silicon Motion also implements 4kB LDPC, providing comprehensive error detection and correction across the memory array.

The SM2270, then, enables the SSD to provide an almost error-free data output to the host. This frees the host to focus on the core functions of data placement and I/O scheduling without having to monitor the integrity of the data input or output, providing a more efficient partition of tasks between the SSD device and the host.

Flexible and high-performance controller solution for Open Channel SSDs

With its support for Open Channel specifications and for custom implementations of the Open Channel concept, the SM2270 from Silicon Motion provides the ideal controller platform for the development of SSDs supporting the new architecture for data centers and cloud computing facilities.

SSDs based on the SM2270 can safely use the latest high-density generations of NAND Flash media while achieving outstanding levels of reliability, a long operating lifetime and high data integrity.

All images in this white paper courtesy of Silicon Motion.