

Shaping NVMe SSD IO Performance in Multi-Virtual Environments

SSDS-102-1: Controllers for the Data Center

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WHY SSDS NEED
PERFORMANCE
SHAPING

HOW DOES SSD
PERFORMANCE
SHAPING WORK

MODELING ->
DEMONSTRATION
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The Challenge of QoS for multi-tenancy is inconsistent tenancy behavior in SSD. Noisy tendency may impact QoS of other tenancies who behaves consistently. Isolation is needed, HOWEVER:

- Restrict isolation (share nothing) has problems:
 - Difficult to implement, challenge to physically divide/isolate resources in the device into small independent pieces
 - Could leads to fragmentation and waste
- NVMe provides submission queue arbitration mechanism based WWR with urgent priority class. But this is limiting:
 - 4 level of priorities/weights
 - Focuses on submission queue level, not in IO command level with performance parameters (IOPS, or throughput as weights
 - No mechanism for arbitration between NVMe controllers on an NVMe subsystem which supports multiple PCIe ports and function

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PerformaShape™ mechanism to shape IO requests per user defined **QoS set**.

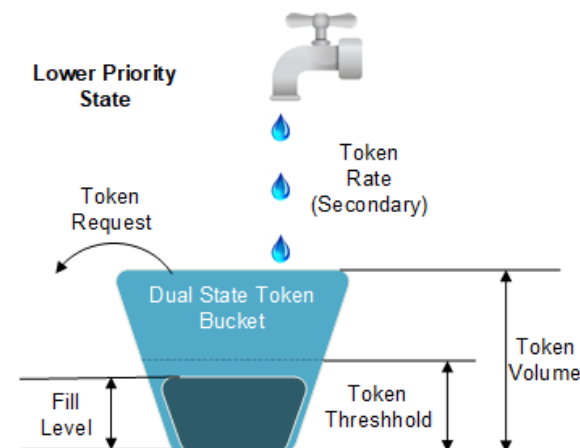
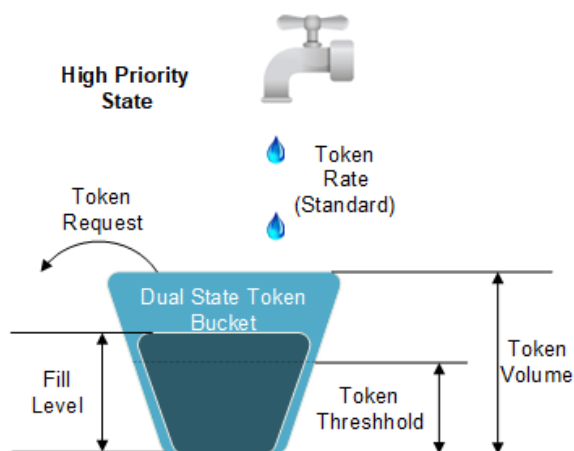
A QoS set is a group of one or multiple host tenants, and/or internal tasks (reclamation, etc.), which initiates IO type operations.

The shaping algorithm is based on **Dual State Token Bucket algorithm**.

- Each QoS set is assigned with a token bucket:
 - One token is a permission for an IO cmd, or some amount of KiB's.
 - Token rate: at which speed tokens fill the token bucket, configurable and variable.
 - Token volume / bucket size: max token number the token bucket can hold.
 - When a QoS set / client requests n tokens:
 - If the bucket has $\geq n$ tokens, grant permission to go.
 - Otherwise, the request waits until the bucket accumulates enough tokens.

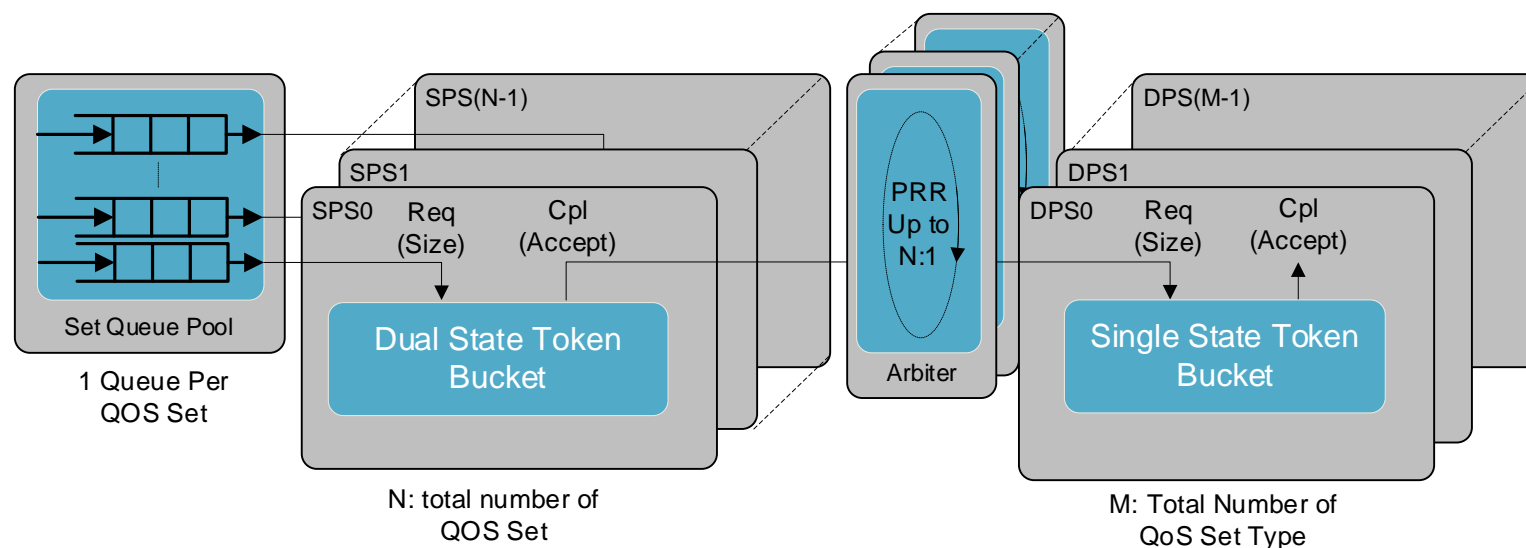
• Dual-State Token Bucket Algorithm:

- Purpose: dual rates to allow the client to request more but given lower priority, processed opportunistically.
- Token fill level \geq token threshold: the token rate will be a standard token rate, and any token request will be accepted with high priority.
- Otherwise, the token rate will be set to a secondary token rate ($>$ standard token rate), and any token request will be accepted with low priority.



• Two-Stage Shaping

- Token bucket shaping smooths IO requests and limits the it's outliers. The dual state token bucket algorism allow more IO burstiness, in order to optimize the utilization of the device bandwidth.
- However, the device bandwidth is limited. When we have multiple noisy/demanding tenants, we need to make sure the device is not over-booked. Thus, we propose a second stage token bucket, namely **Device Level Token** bucket:
 - Simply one-state token bucket with a token rate = device bandwidth
 - Can have multiple of it used for different type of IO performance controls, e.g. IOPS, throughput (GB/S), read and write, etc.



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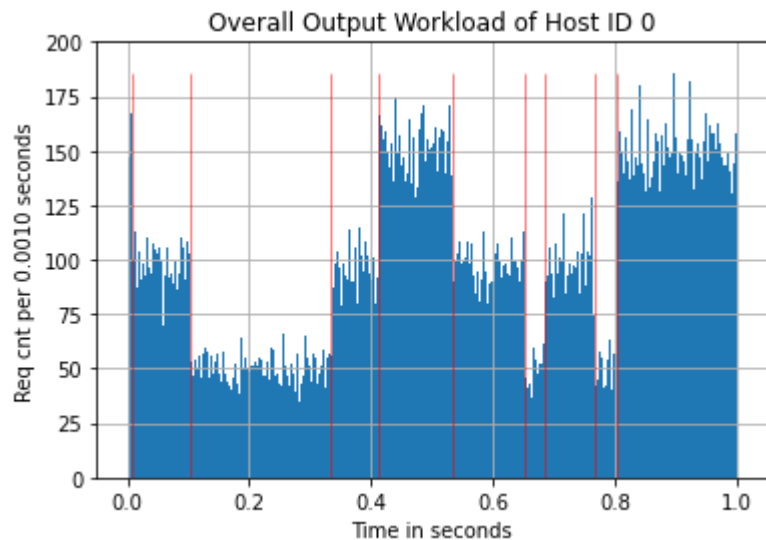
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Performance Shaping Modeling Goals

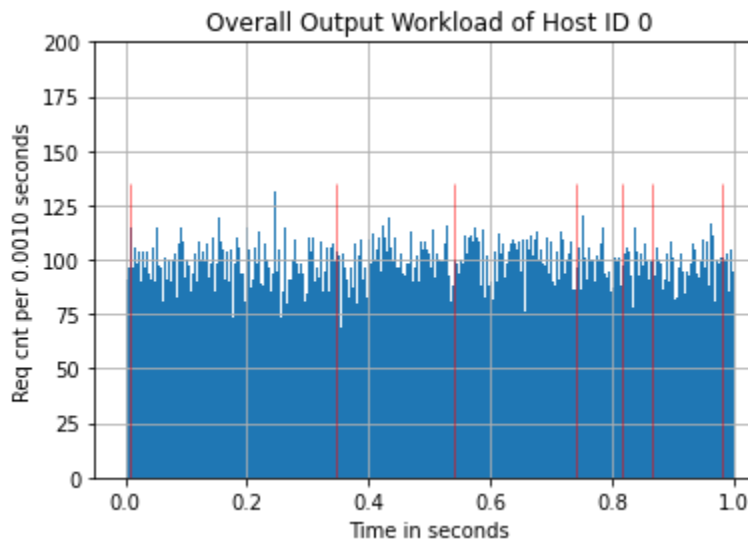
- ☐ Smooth out fluctuations
- ☐ Isolate noisy neighbors
- ☐ Fully utilize the SSD bandwidth

Key Modeling Components

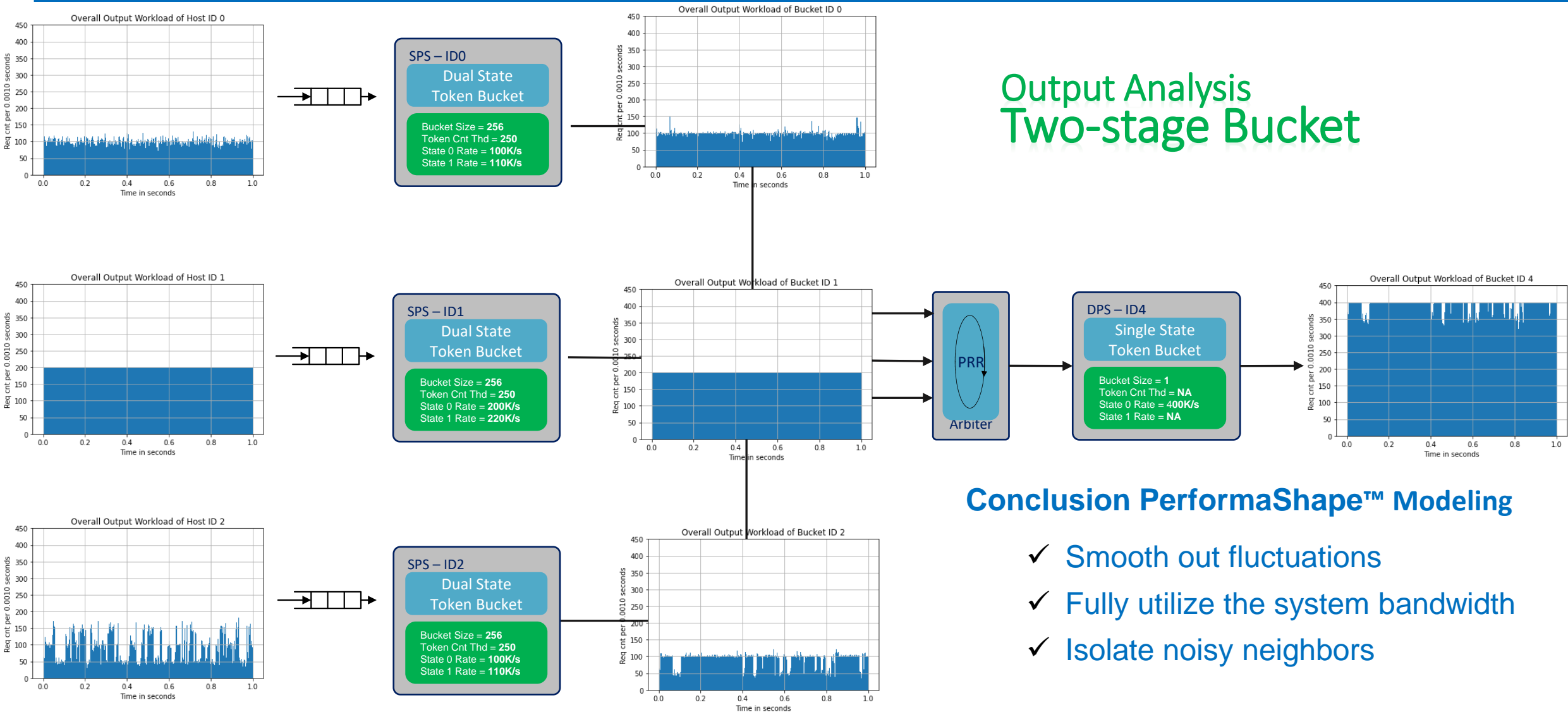
- ☐ Host Workload Generator
- ☐ Simulator
- ☐ Output Analysis



- Poisson's: 100K/150K/50K
- Noisy neighbor



- Poisson's: 100K/100K/100K
- Good neighbor

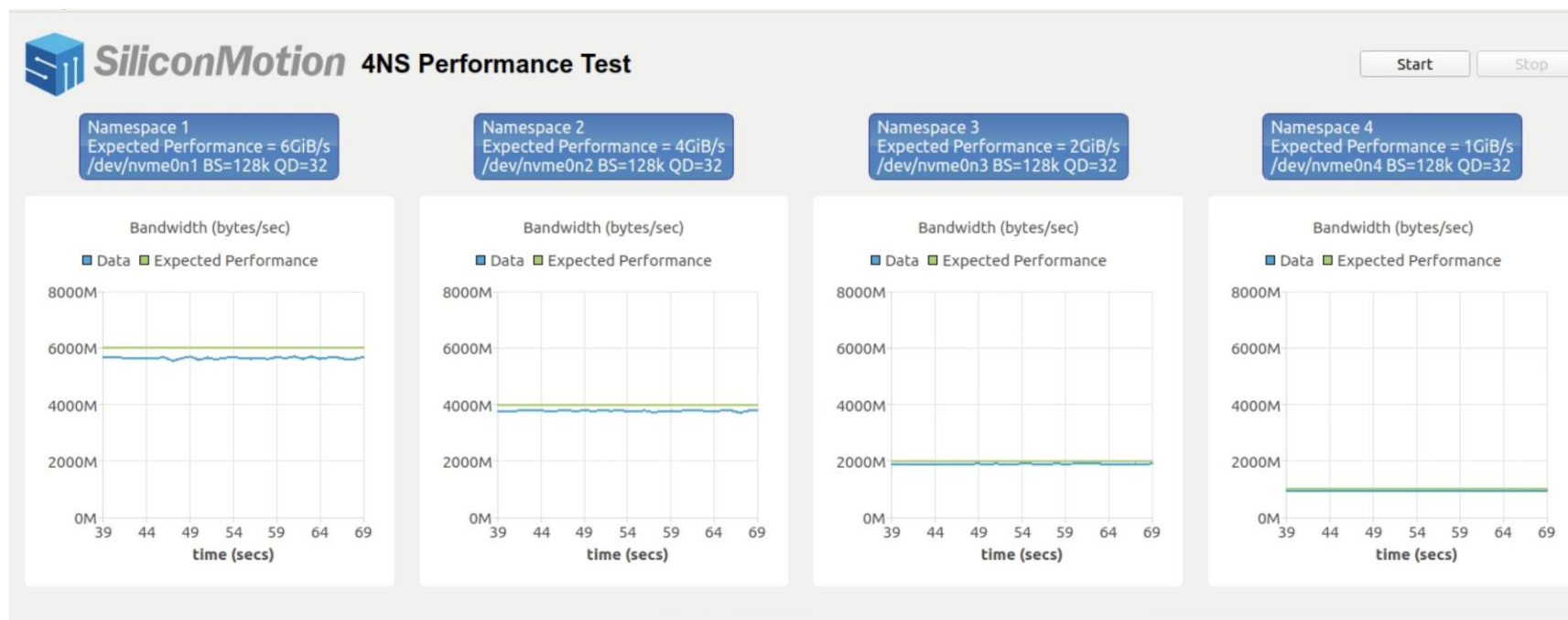


Conclusion PerformaShape™ Modeling

- ✓ Smooth out fluctuations
- ✓ Fully utilize the system bandwidth
- ✓ Isolate noisy neighbors

NS	Measurement	Performance Shapping Engine		Host Setting
		SPS Setting	DPS – ID4	
NS0 – ID0	5.97GB	6GB/S (8083)	12.9 - 13GB/s	6GB/S (5723MiB)
NS1 – ID1 – Noisy	3.98GB	4GB/S (12125)		6GB/S (5723MiB)
NS2 – ID2	1.99GB	2GB/S (24250)		2GB/S (1908MiB)
NS3 – ID3 - Noisy	0.96GB	1GB/S (48500)		2GB/S (1908MiB)

- ✓ 16GB/S Read Requests from Host in 13GB/S system
- ✓ Isolates and Guarantees Performance per Tenant
- ✓ Removes Noisy Neighbors



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