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High Availability for Centralized NVMe

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Abstract

- High Availability for NVMe

  Using NVMe drives in a centralized manner introduces the need for high availability. Without HA, a simple failure in the NVMe enclosure will result in loss of access to a big group of disks. Loss of a single NVMe disk will impact all hosts mapped to this disk.

  During this presentation, we will review the state of the industry regarding approaching these problems, the challenges in performing HA and RAID at the speeds and latency of NVMe, and introduce new products in this space.

Introduction

- Since the introduction of NVMe drives in 2014, they have been rapidly adopted for use as cache, in-memory DB extension, fast tier of SSDs, fast boot devices, etc.
- NVMe adoption is across the board, starting from laptops through servers/IaaS to HPC
- However, until now, NVMe drives have only been used as local drives in servers
- Redundancy schemes were handled by the applications

Benefits of local NVMe

- Latency
- Bandwidth + Throughput: 6x compared to SAS/SATA
- CPU utilization
- Protocol efficiency (no need for SAS/SATA stacks)
- Less hardware needed (SAS/SATA controllers)
- Highly accepted standard, rich roadmap ahead
- Newly available 2.5” form factor allows for easy replacement of drives

Problems with local NVMe

- Redundancy / Resiliency
  - What happens to my data if an NVMe drive fails?
- Provisioning
  - I need to decide, per server, how much NVMe capacity to provision it with
  - What if my servers run out of capacity?
- “Islands of Storage”
  - Efficiency of NVMe allocation: customers surveyed indicate that on average, 30% of the SSDs capacity is utilized
- Coupling of storage and compute
  - Need to buy storage now, that I will be using for the next 4-5 years
  - Marriage of life-cycle of storage and compute

So… what about NVMe sharing?

- If one could share NVMe drives between multiple servers, there would be…
  - Redundancy / Resiliency
  - No more “islands of storage”
  - Storage-compute de-coupling (aka flash dis-aggregation)
  - Dynamic provisioning
    - Increase NVMe capacity per server – dynamically
  - LUN sharing
    - Many concurrent reads on large data-sets
    - LUN sharing for application clusters

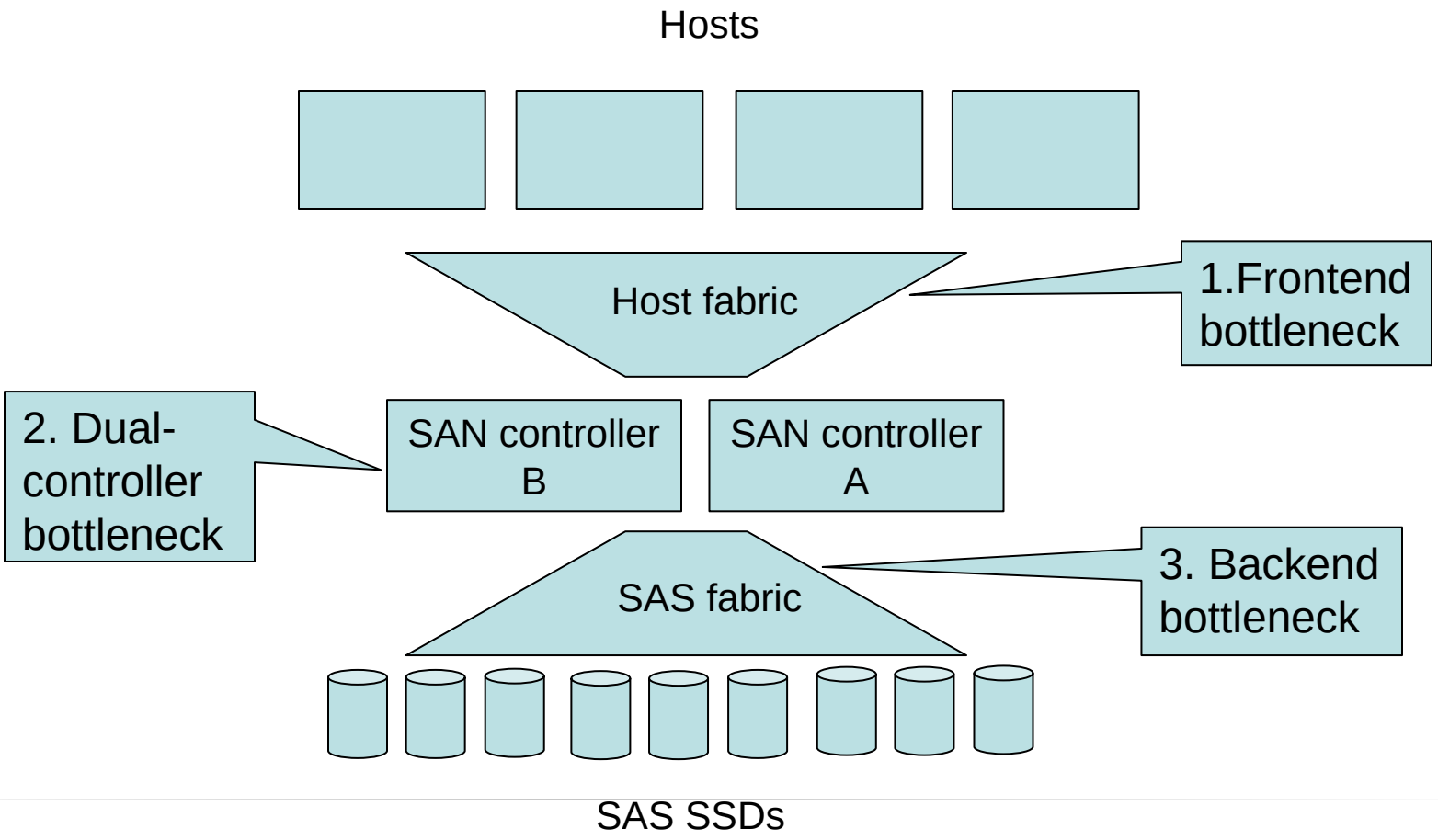
But what about performance?

- Remoting the NVMe SSDs from the server will impact latency
- **Challenge #1: retain remote latency on par with local latency**
  - (*or as close as possible)
- Bunching many SSDs in a box creates a throughput/bandwidth explosion
- **Challenge #2: get all the available bandwidth/throughput of remote NVMe**

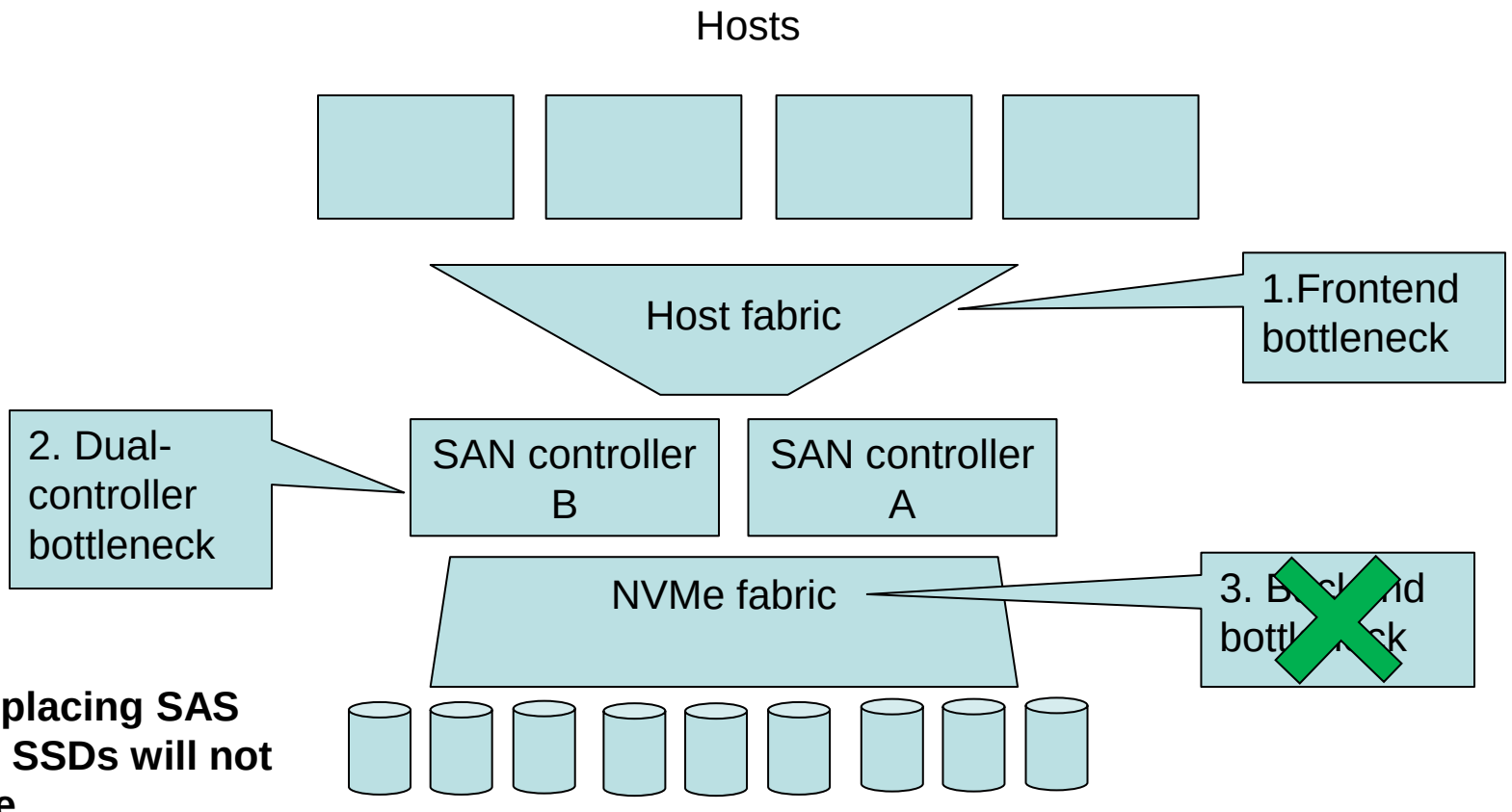
So let’s use NVMe in our SAN

- Why not use NVMe as a SAS or SATA replacement in our SAN?
- In traditional and even in modern SAN arrays, even AFAs, **SSD connectivity is not the bottleneck**
- The I/O stack of the storage controller is the bottleneck
- Replacing SAS/SATA SSDs with NVMe SSDs will lead to little performance improvement if any at all
- **SAN with NVMe ~= SAN without NVMe**

Traditional SAN design



SAN design + NVMe



Merely replacing SAS for NVMe SSDs will not obtain the improvement.

Is the SAN adequate for NVMe?

- Single NVMe SSD = Up to 4GB/s (32 Gbps)
- Typical FC deployment = 16Gbps
- A 2U24 NVMe box would require 48 (!) FC16 ports

- **Remote NVMe requires a low-latency high-bandwidth network**

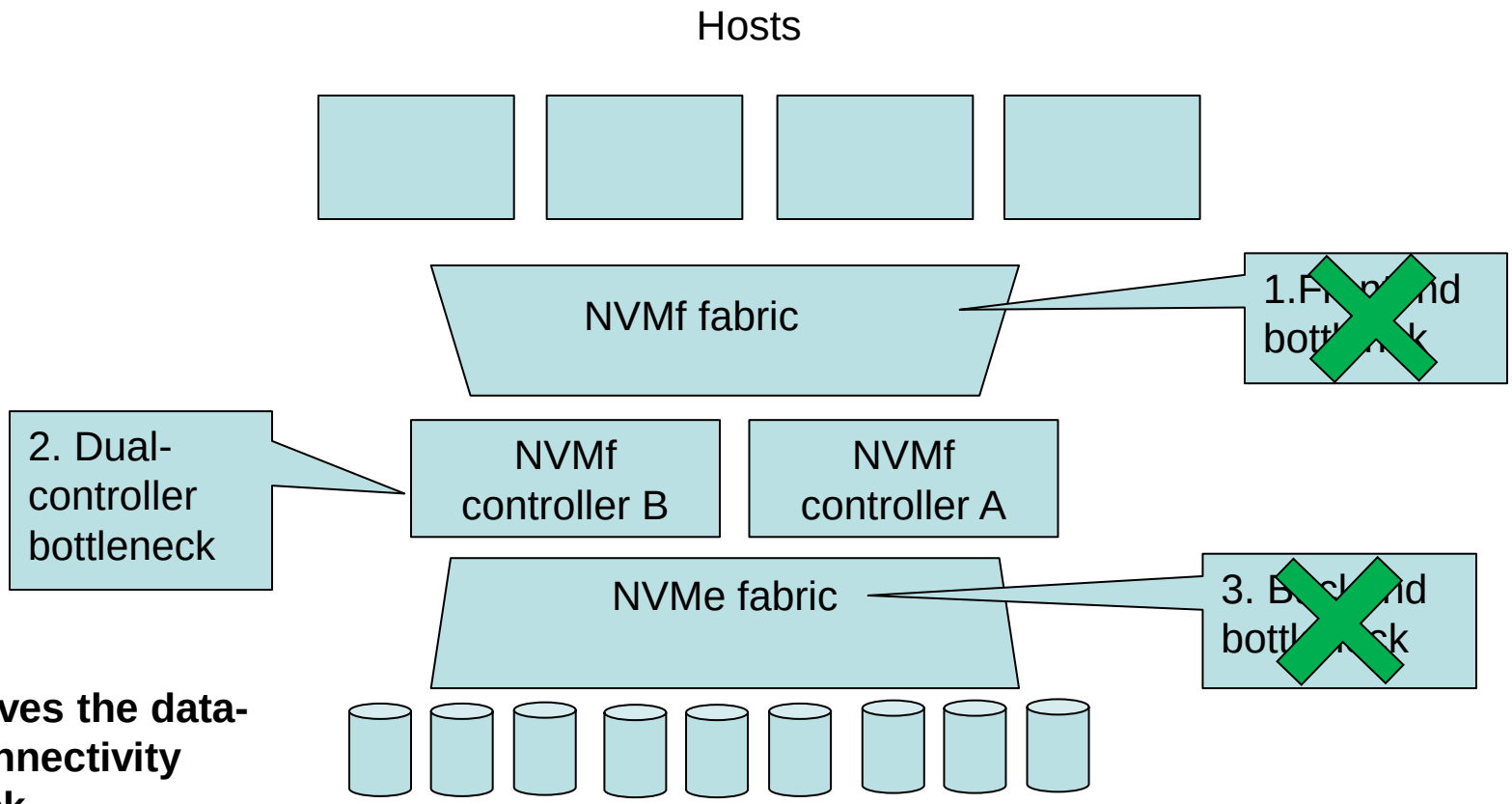
Enter NVMf

- NVMe over Fabrics standard addresses the challenge of accessing remote NVMe subsystems
- NVMf v1.0 standard was ratified in June 2016

NVMf solves data-path performance

- NVMf fabrics include:
  - High-bandwidth Ethernet (e.g. 40GE, 100GE)
  - Infiniband (e.g. 56G IB, 100G IB)
  - FC (e.g. FC32, FC128)
- Corresponds with transition of the data center from 10GE/40GE DL/UL to 25GE/100GE DL/UL
  - Server ports: 10GE → 25GE
  - Storage ports: 40GE → 100GE
  - Instead of 48 16G FC ports, use 8 * 100GE/FC128 ports
- NVMf guideline: no more than 10us of additional latency
- Such networks have the needed bandwidth/throughput

SAN design + NVMf



NVMf solves the data-path / connectivity bottleneck.

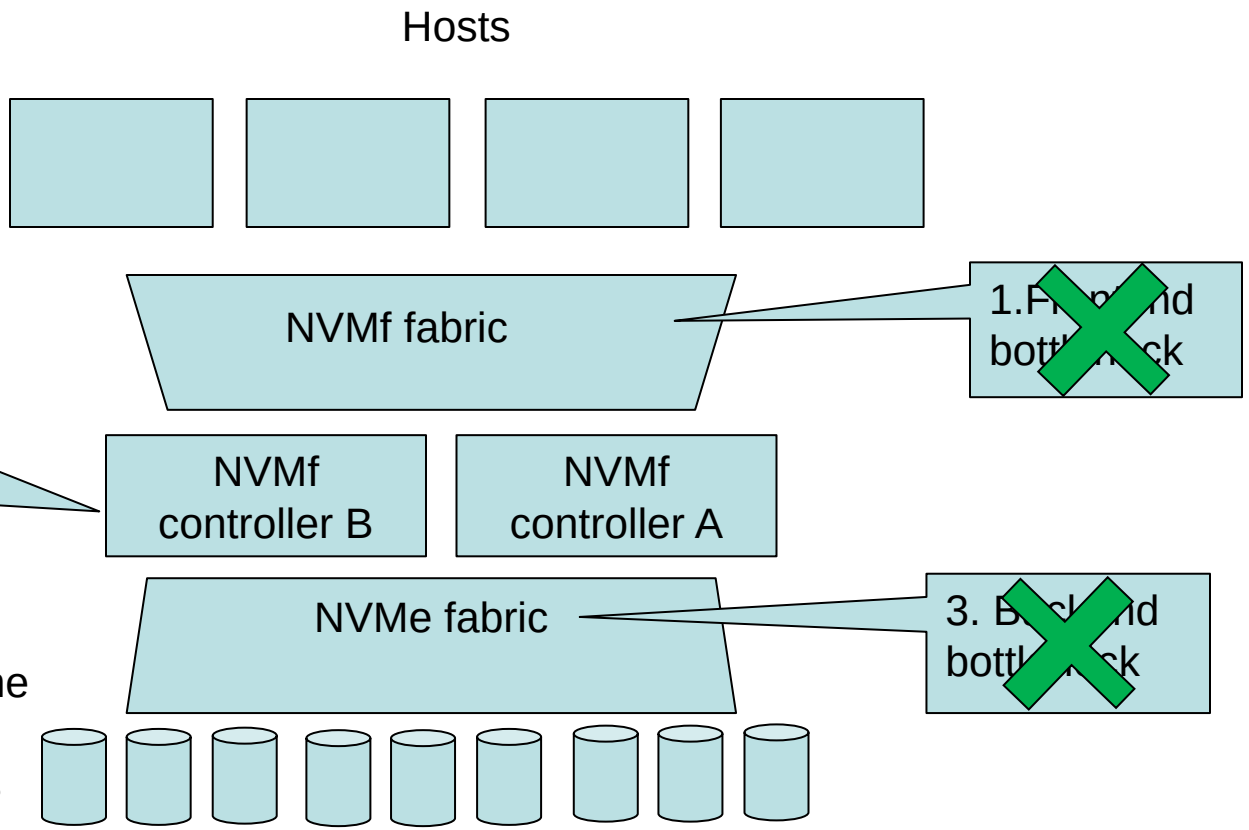
Importance of RDMA for NVMf

- RDMA allows one machine to access the memory of another machine without going through its CPU
- Why is this important?
  - Lower CPU utilization on the hosts
  - Allows for “direct placement” approach in the targets
  - Lower end-to-end latency
- RDMA
  - A native property of InfiniBand fabrics
  - Available on Ethernet: RoCE
  - Available on TCP/IP: iWARP

NVMf and the I/O stack

- NVMf allows a client to access a remote box of NVMe with low latency and high bandwidth/throughput
- But… it doesn't solve the I/O stack challenges
- How is resiliency implemented in NVMf?
- Is there RAID in NVMf?
- Snapshots?
- Replication?
- Thin provisioning?
- **NVMf only formalizes the access protocol (like SCSI).**
- **NVMf doesn't explain how to implement features.**

SAN design + NVMf

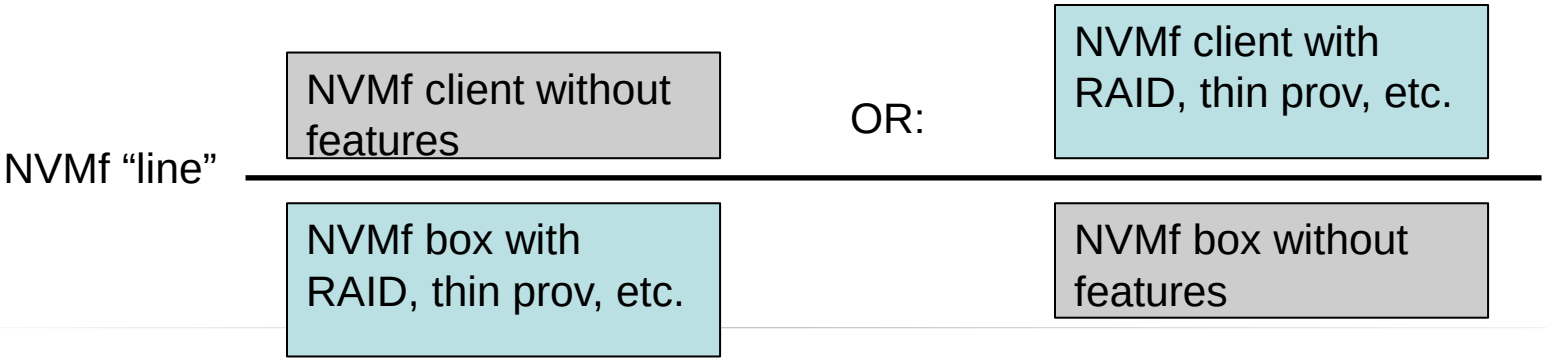


Q: Does the controller **do** anything?

If YES: dual-controller is the bottleneck still.
If NO: **where are features implemented?**

The dividing line

- NVMf is the dividing line:
  - Features like RAID or thin provisioning can be implemented either **below** the line (in the NVMf target) or **above** the line (in the NVMf host)
- Implement features below the line = scale-up solutions
- Implement features above the line = scale-out solutions

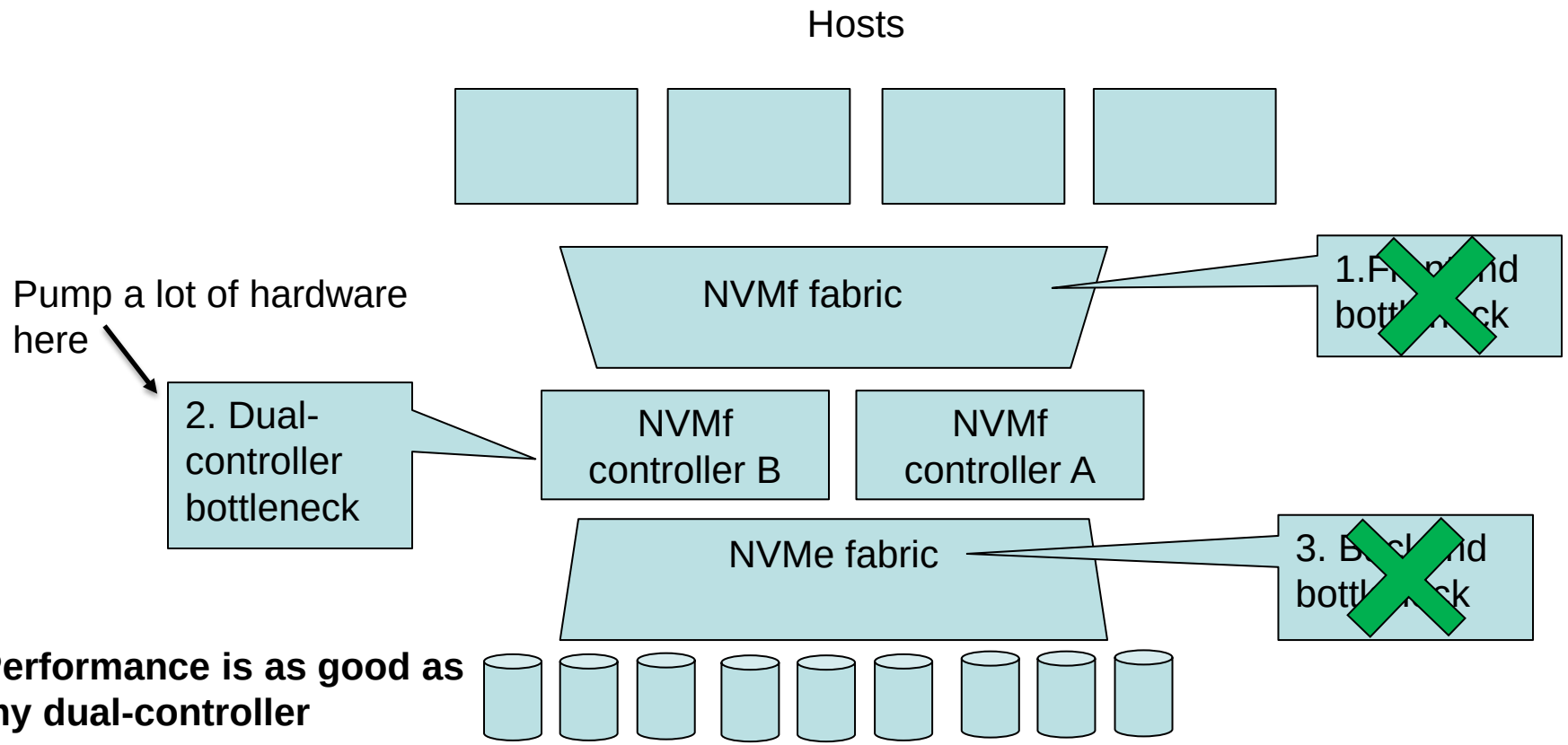


Scale-up solutions

- “Below the NVMf line” solutions implement RAID, thin provisioning, etc. within the NVMe/NVMf appliance
- Performance is as good as the hardware performing these operations – classic scale-up
- Can lead to hardware-centric solution
  - Hardware RAID implementation
  - Hardware-optimized data structure

- **Hardware-defined NVMf approach implements storage features in the appliance.**

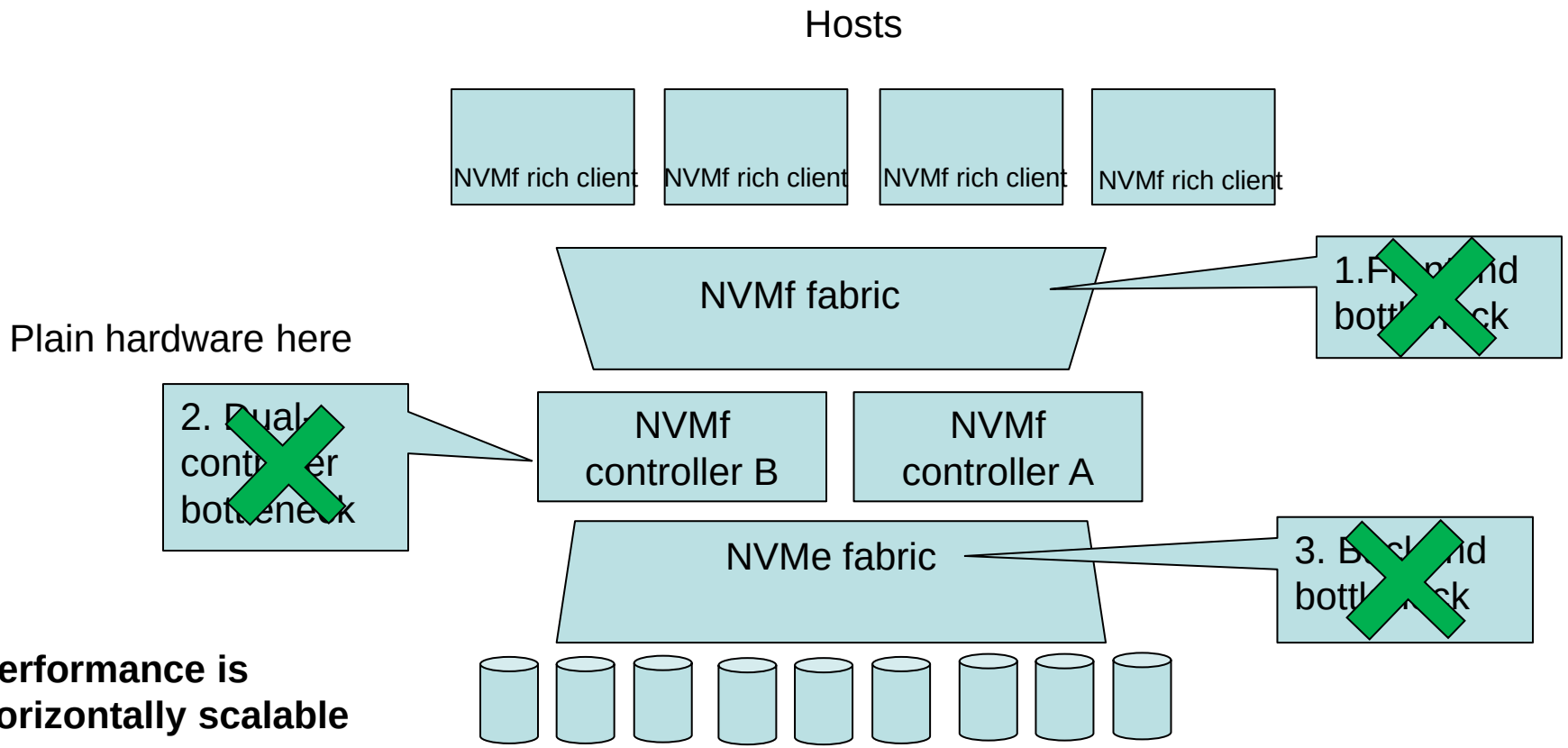
NVMf: Scale-up



Scale-out solutions

- “Above the NVMf line” solutions implement RAID, thin provisioning, etc. **outside** the NVMe/NVMf appliance
- **Scale-out** the implementation to many small entities
- Requires a fast-enough network
  - NVMf requires that anyway
- Ideally a switchable (L2) network
  - FC, Ethernet & IB are switchable
- Would benefit from a routable (L3) network
  - ROCEv2 and iWARP are routable
- **Software-defined NVMf approach implements storage features outside the appliance.**

NVMf: scale-out



Performance is horizontally scalable

Challenges with scale-out NVMf

- How are the different entities coordinated?
- What happens when an entity fails?
- How are LUNs shared in this approach?

- Requirements:
  - Network resiliency, multi-pathing
  - Host failure resiliency
  - Efficient SSD redundancy scheme, replicas provide no improvement over local NVMe usage
  - Enclosure redundancy scheme
  - Enclosure high availability

Benefits of scale-out NVMf

- Scalable in number of SSDs
  - Able to extract the entire bandwidth & throughput of the SSDs
- Scalable in number of network ports
  - Add more ports → get more bandwidth
- Scalable in number of NVMe enclosures
  - Add more enclosures to get more capacity and performance
- Scale to hundreds of servers

Comparison of the 2 approaches

Scale-up	Scale-out
NVMf target ("Below the line")	NVMf host ("Above the line")
Hardware-centric	Software-centric
Performance is as good as the scale-up controller	Get the entire performance of all SSDs – no single controller
Add more SSDs? → HW change	Add SSDs easily
Add more networking ports? → HW change	Increase number of network ports and network rate easily
Aggregate enclosures? → HW change	Stack SSD enclosures easily
Add more hosts? → HW change	Scale to hundreds of servers
Segregated network	Converged network
Future = more hardware revisions	Future-proof

Summary & Conclusion

- NVMe is radically changing data centers
- NVMe in local usage is well understood
- Opportunity for NVMe in shared usage has tremendous value and benefits for customers
- Shared NVMe introduces performance and scalability challenges
- Newly available dual-ported NVMe SSDs and the NVMe over Fabrics standard are enablers for shared NVMe
- While the problem lends itself to hardware solutions, a scale-out software-centric NVMf solution will provide greater robustness and scalability