Is Bare-metal I/O Performance with User-defined Storage Drives Inside VMs Possible?

Benchmarking libvfio-user vs. Common Storage Virtualization Configurations

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McGill UNIVERSITY

CHEOPS ‘23
May 8th, 2023
Rome, Italy

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Virtualization is everywhere

- Datasets keep growing
- We want storage to be efficient

Source: Intel [1]. An Intel Optane PCIe NVMe SSD.

Source: Google [2]. Inside a Google Datacenter.

aws

Azure

Google Cloud Platform

What is missing from storage virtualization?

1. Good performance with loose coupling
2. Rapid device prototyping
3. Live migration
4. Userspace drivers

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What is missing from storage virtualization?

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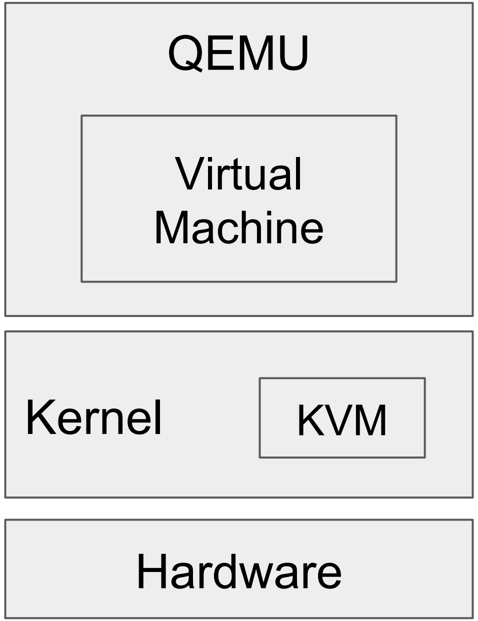
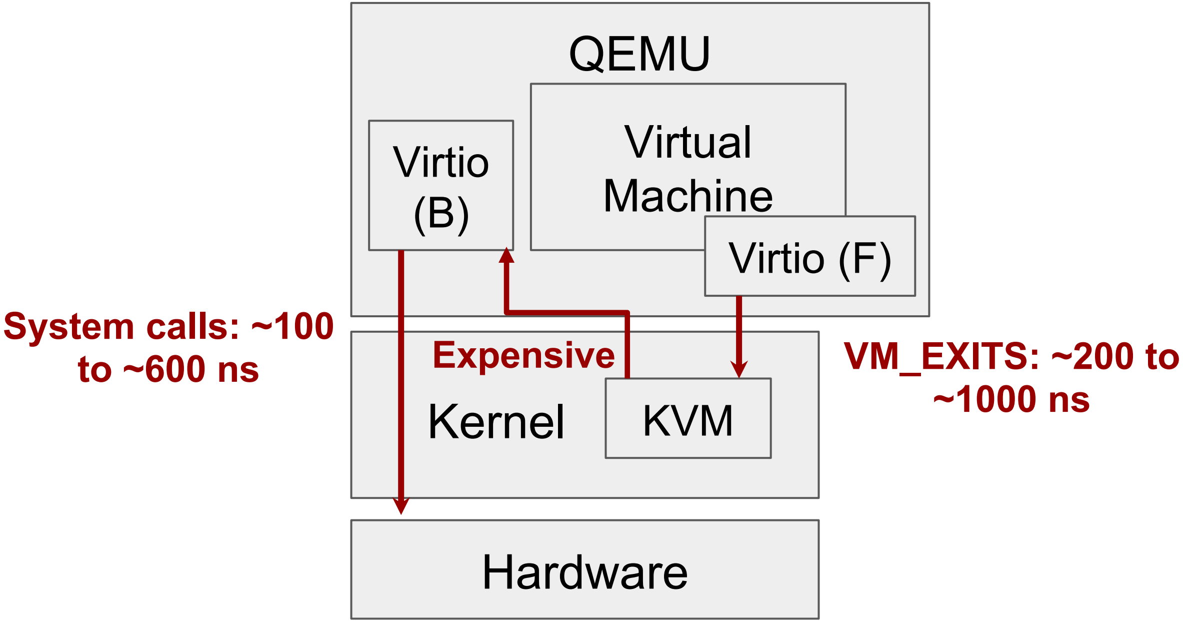
vfio-user

Can **vfio-user** be used as an alternative to current VM storage?

Virtualization and QEMU/KVM



Context switches are expensive



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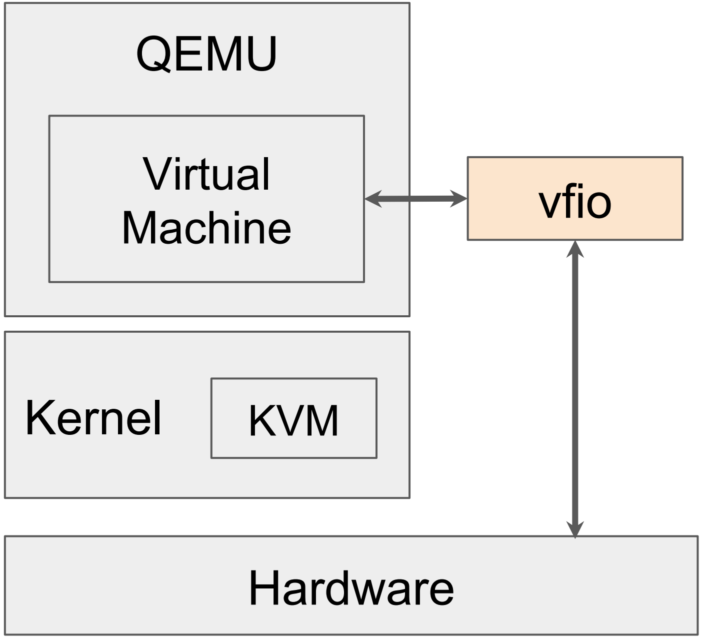
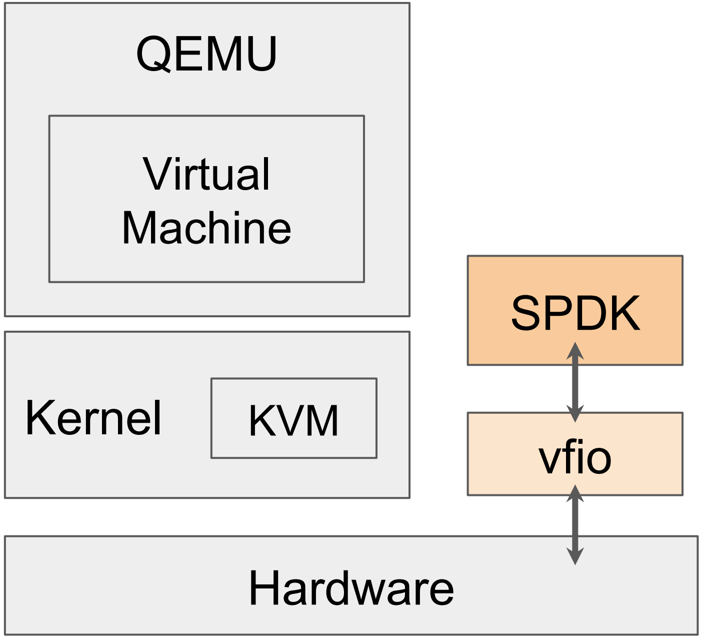
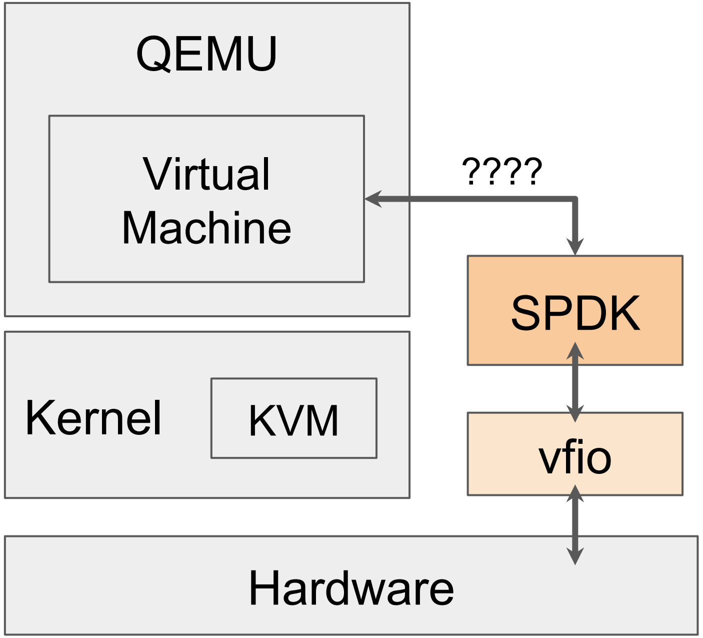
Userspace hardware access



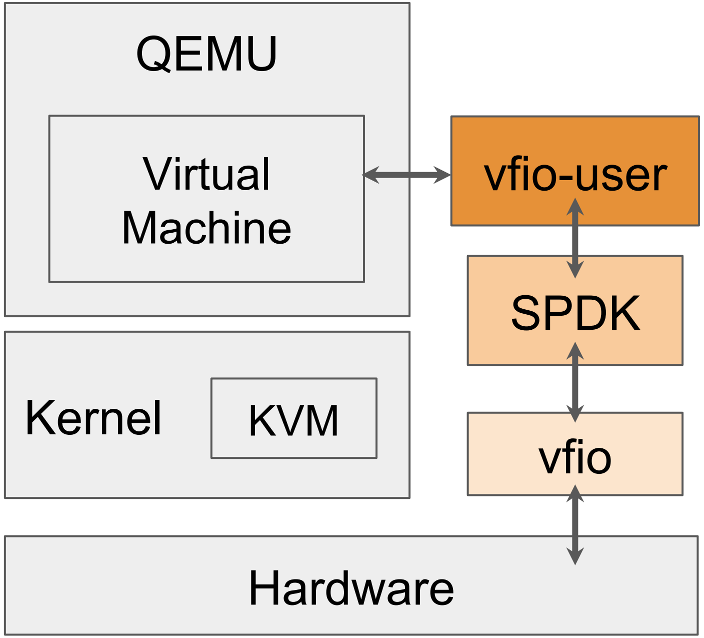
Abstracting hardware access



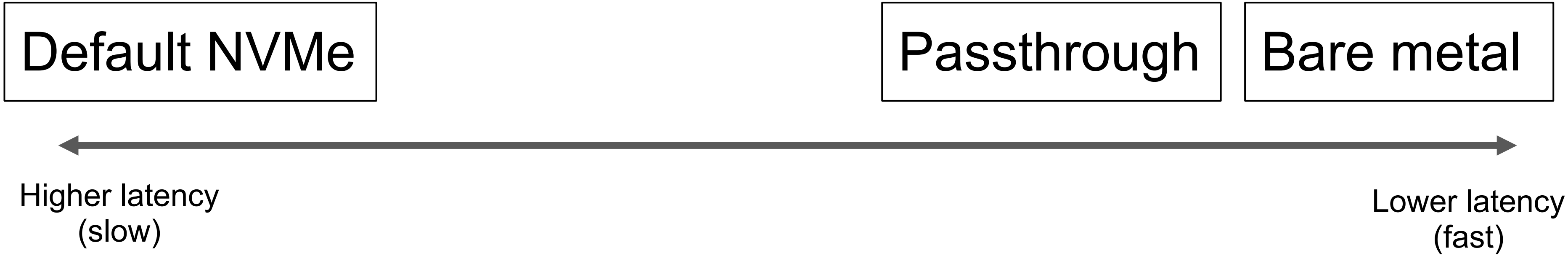
How do we connect after abstracting?



Vfio-user virtualizes hardware over a channel



I want my process to see an NVMe



Default NVMe

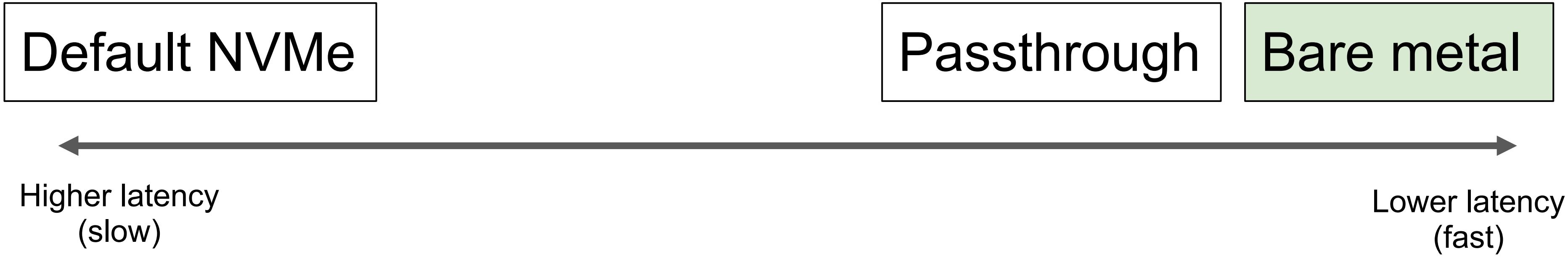
Passthrough

Bare metal

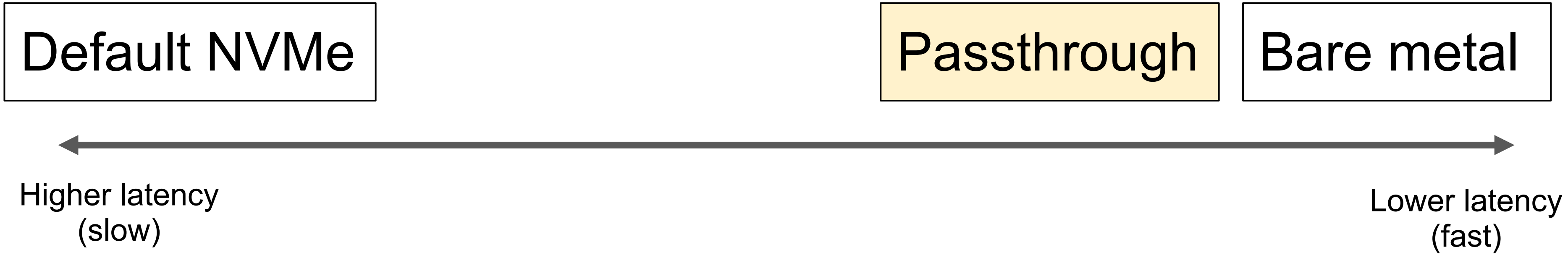
Higher latency
(slow)

Lower latency
(fast)

Fast and simple



Fast, involves some configuration



Default NVMe

Passthrough

Bare metal

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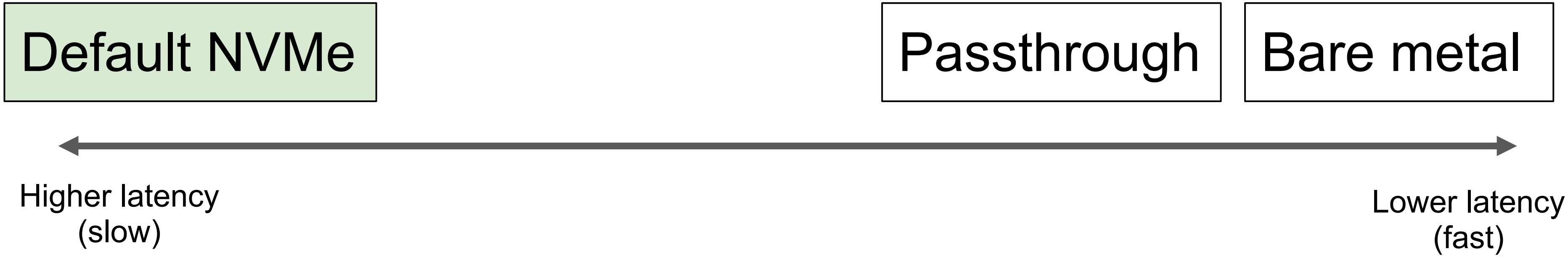
Slow, requires one command-line flag



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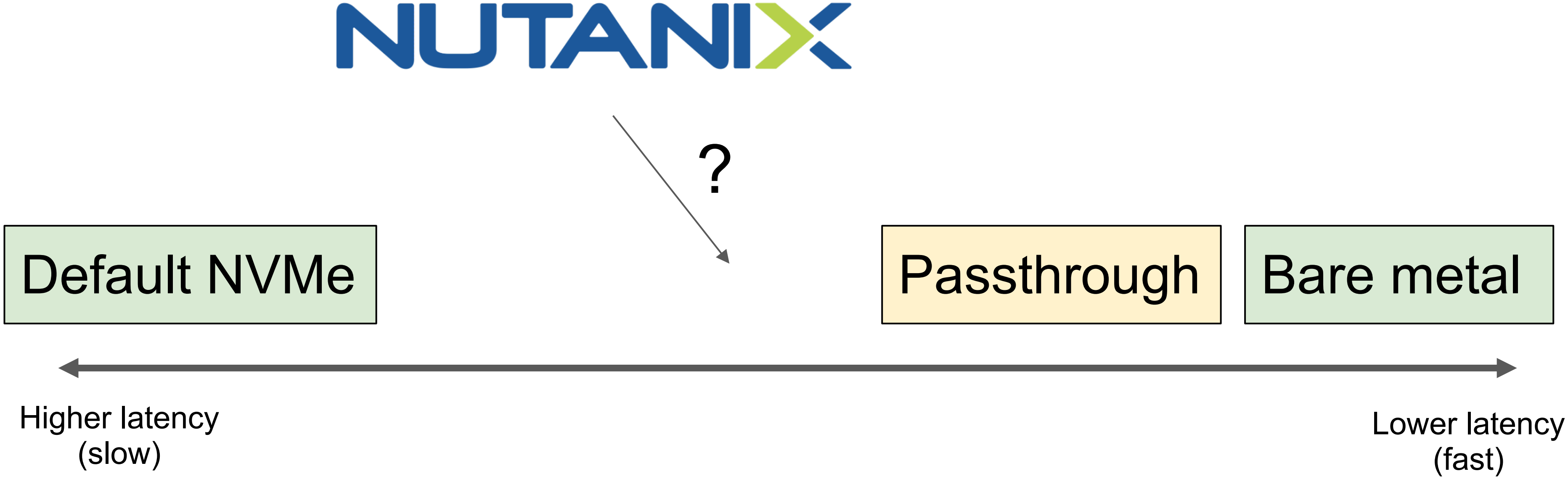
Where does vfio-user fit?



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Default NVMe

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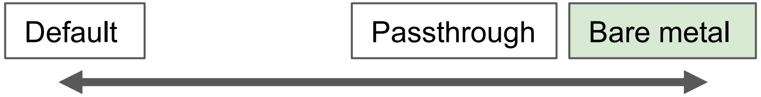
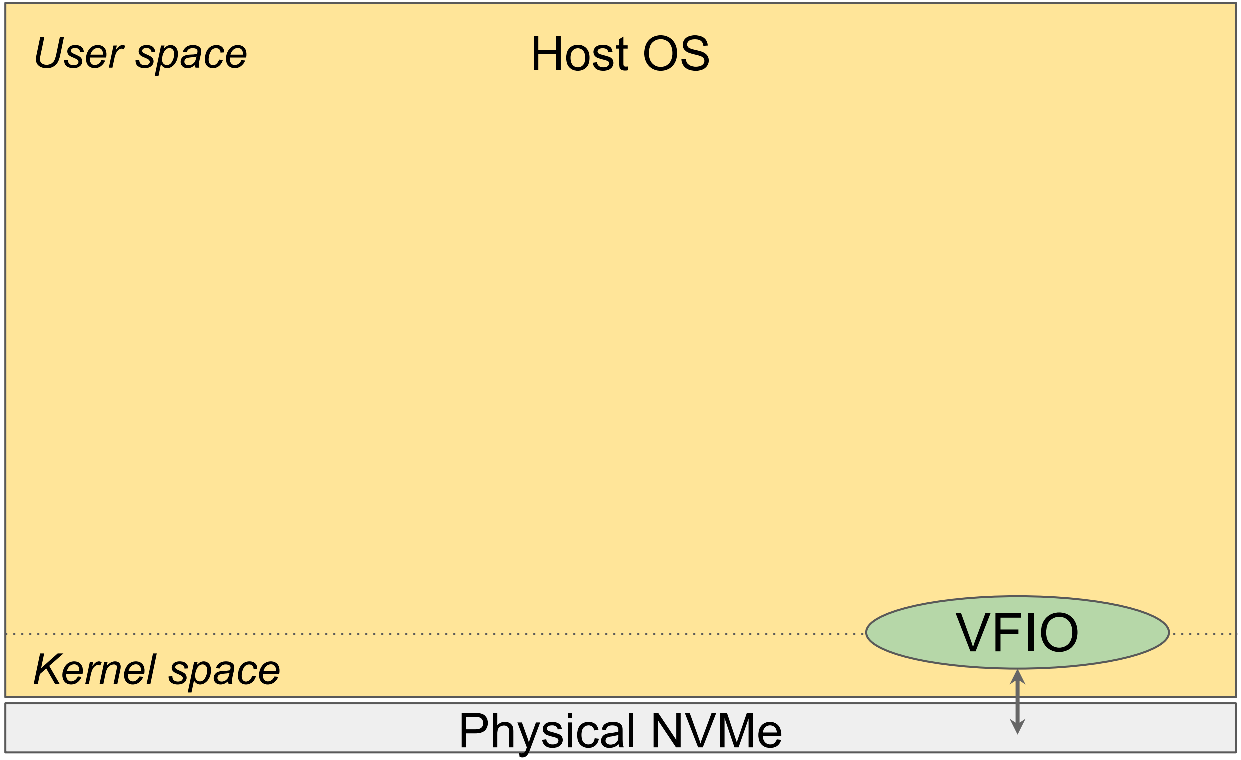
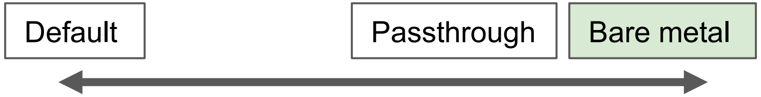
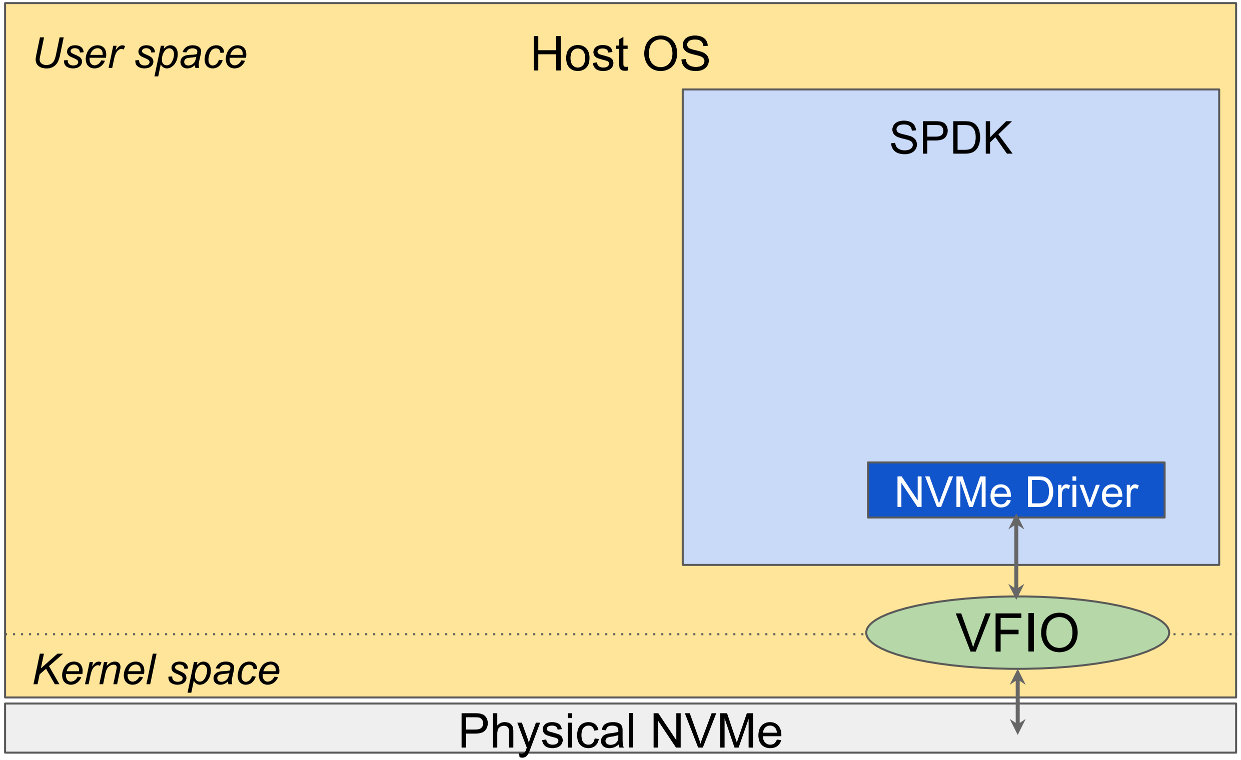
Bare metal configuration





Bare metal configuration





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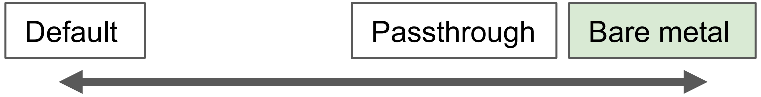
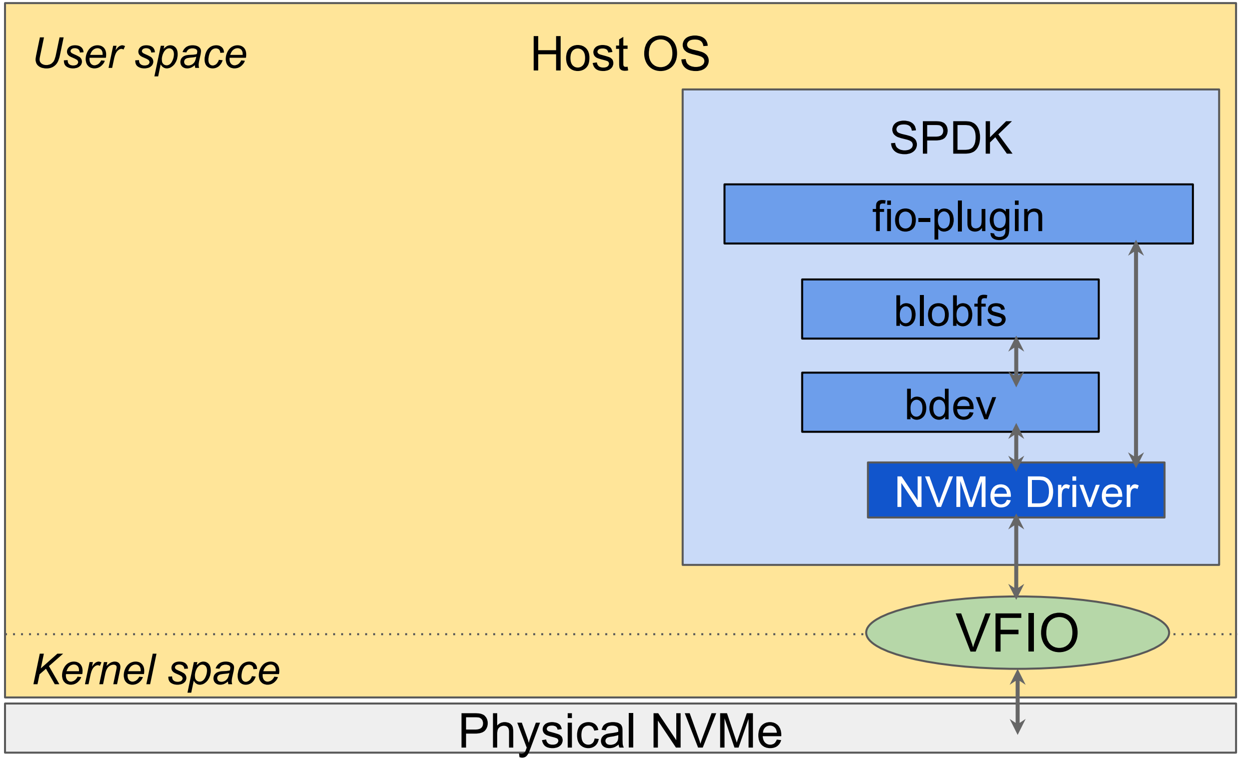
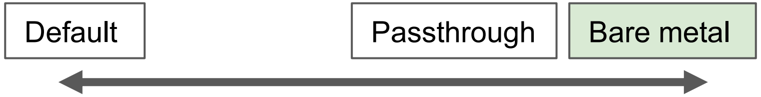
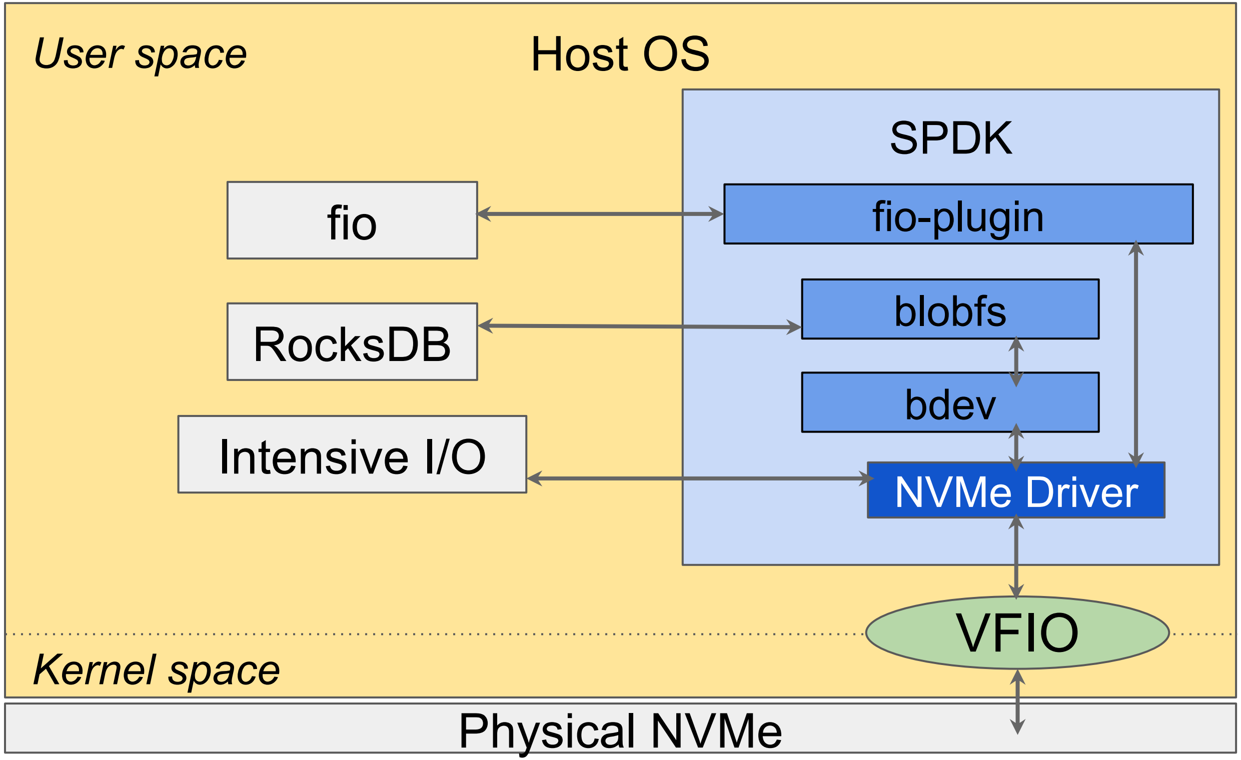


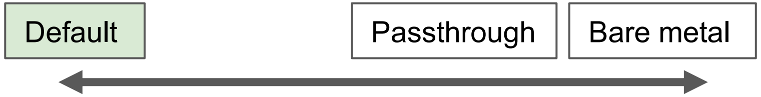


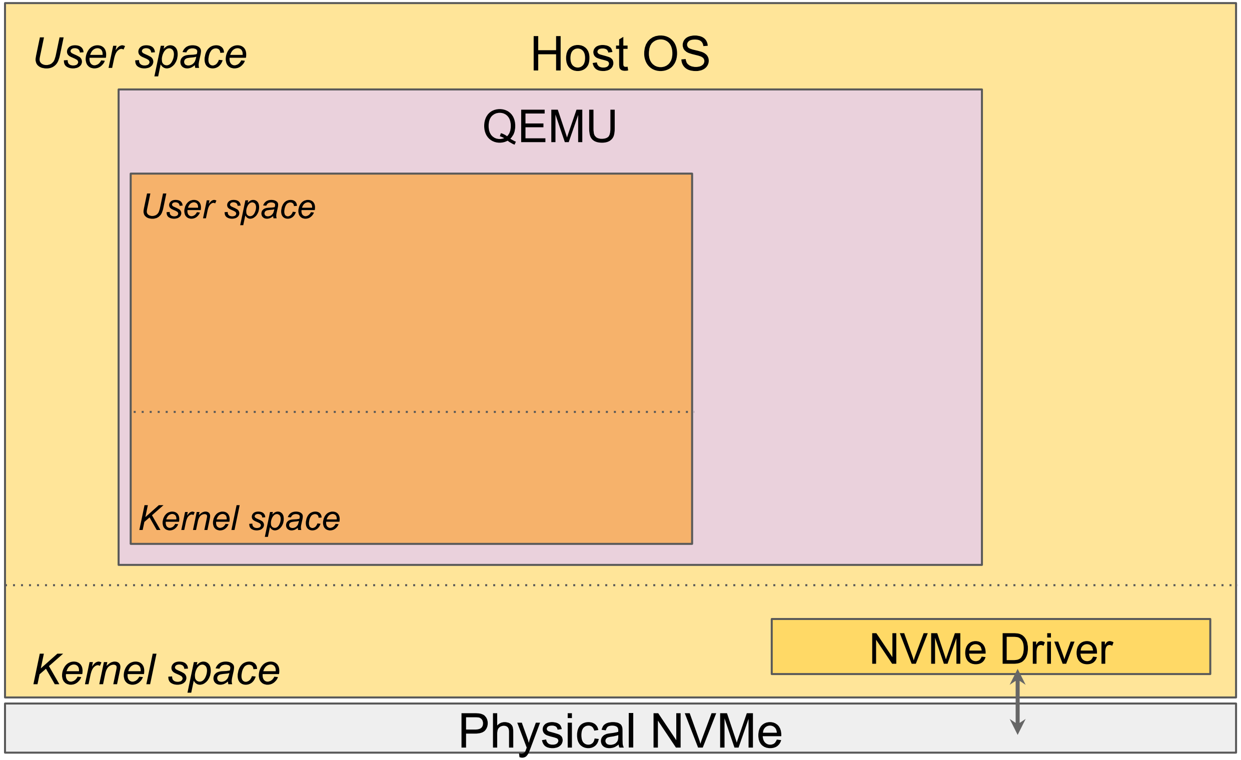
Bare metal configuration





Default NVMe configuration





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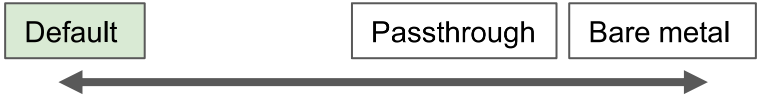

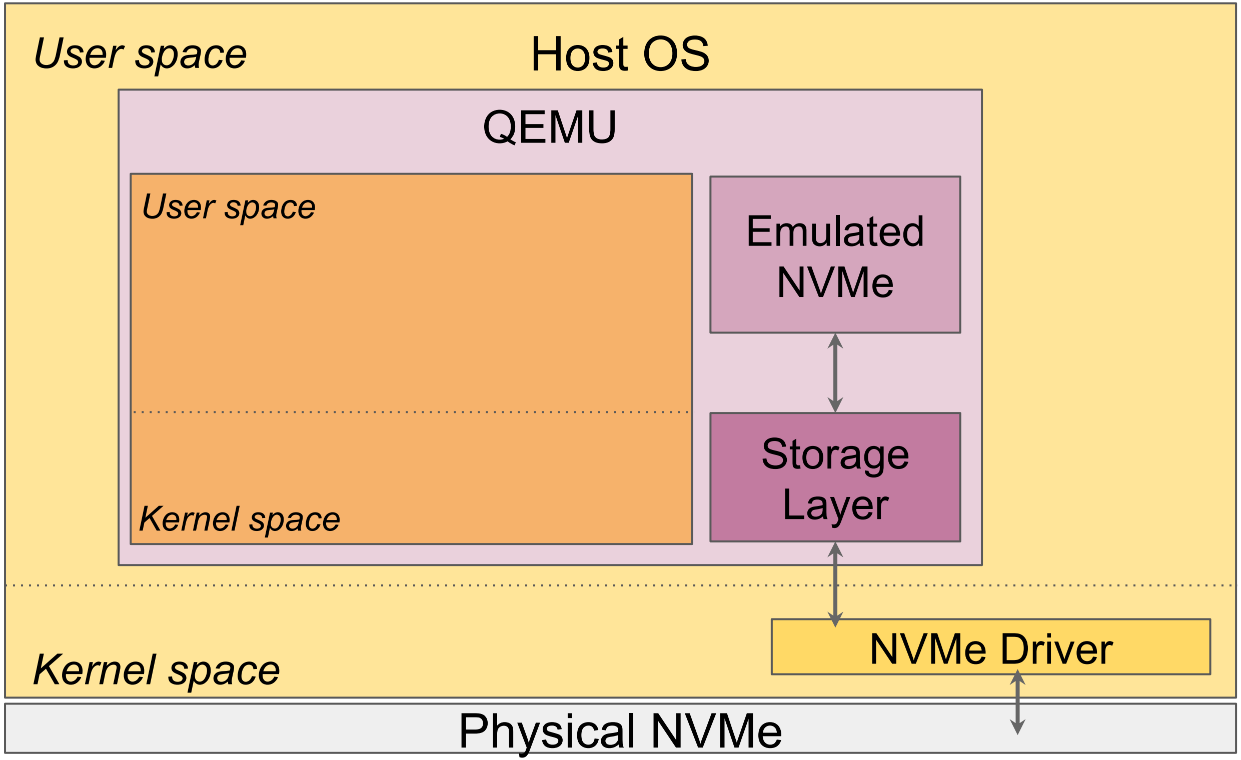

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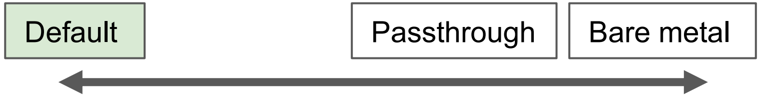

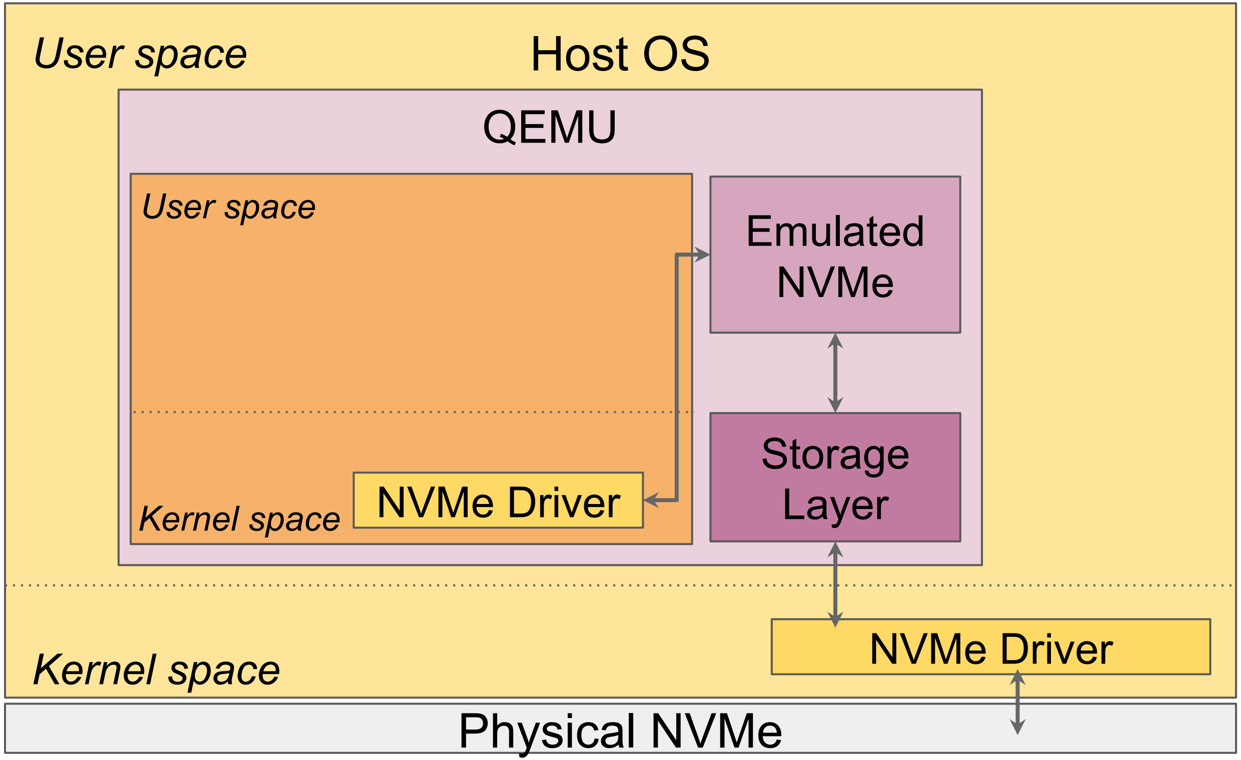

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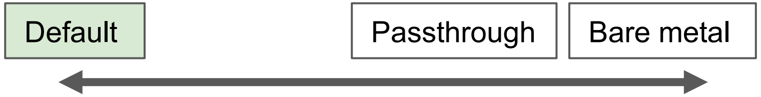
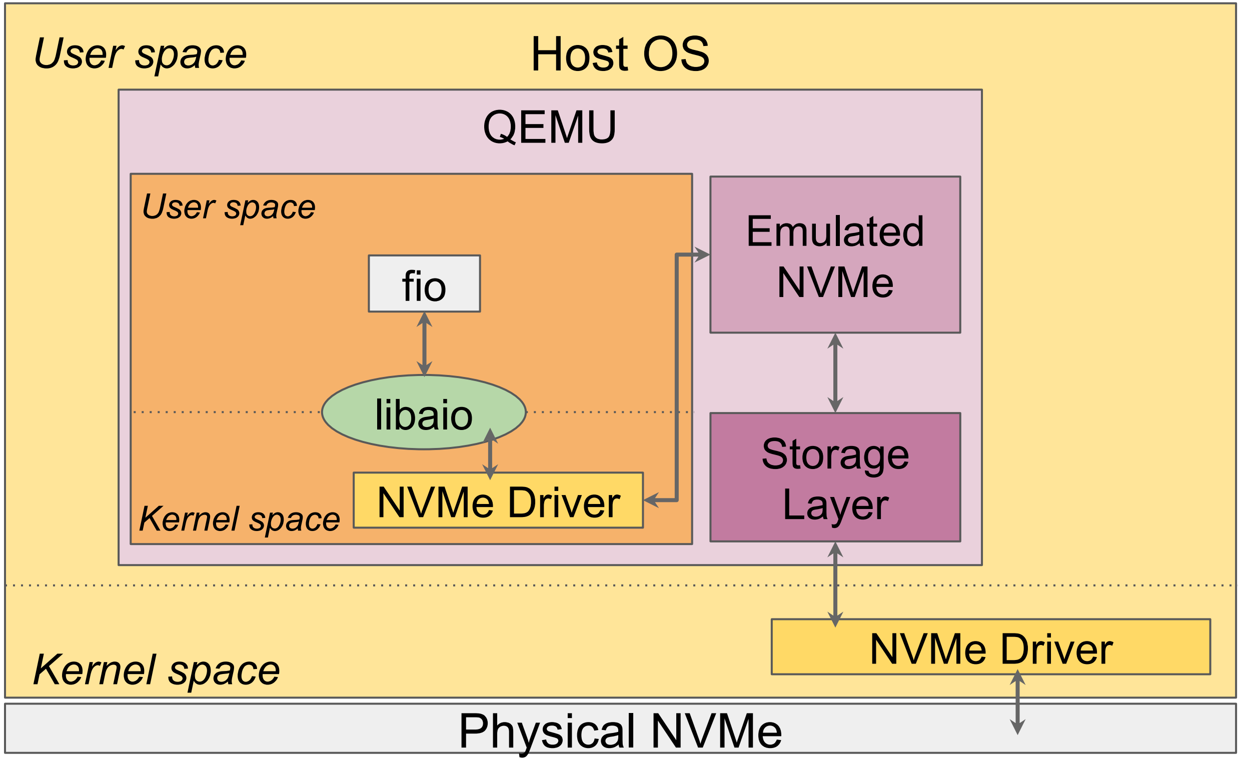
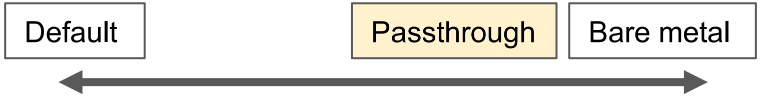
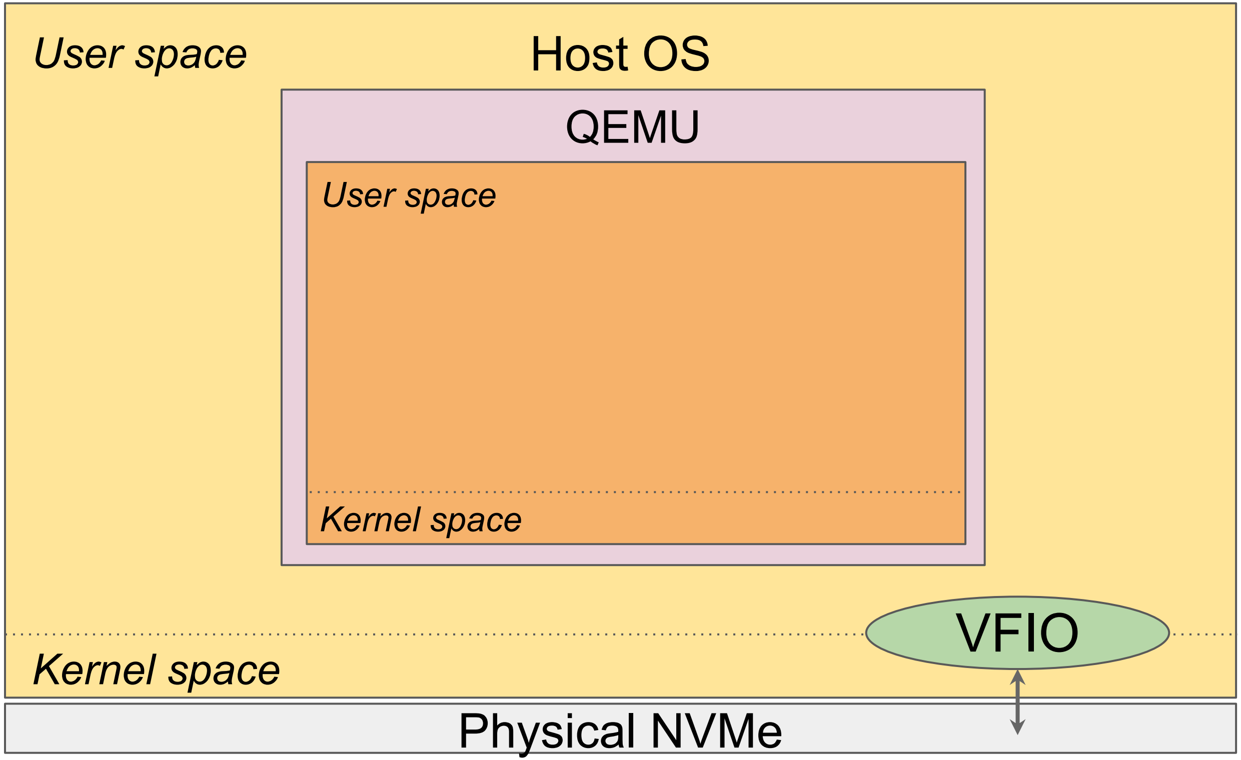




Passthrough configuration





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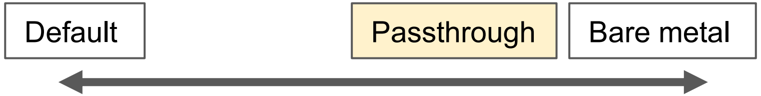

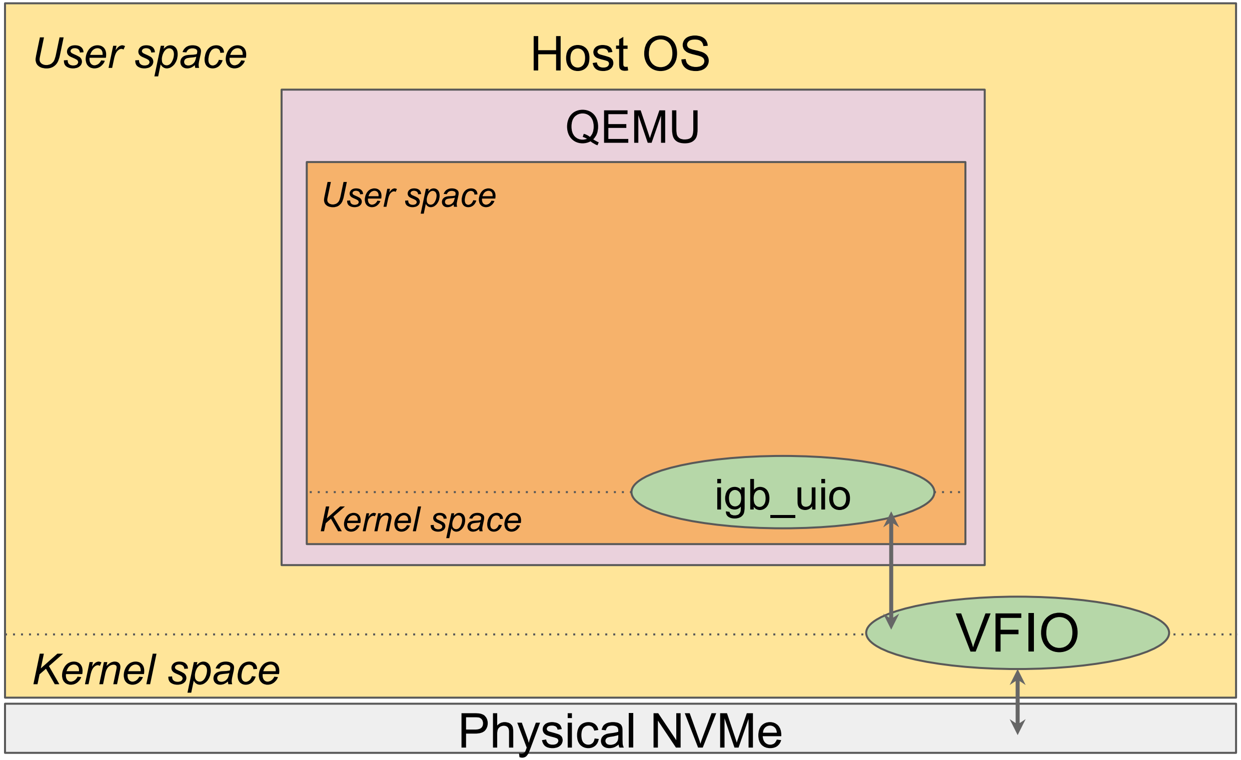

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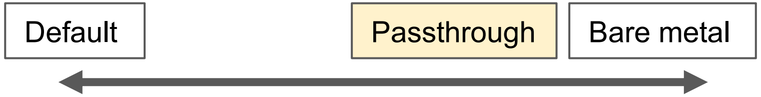
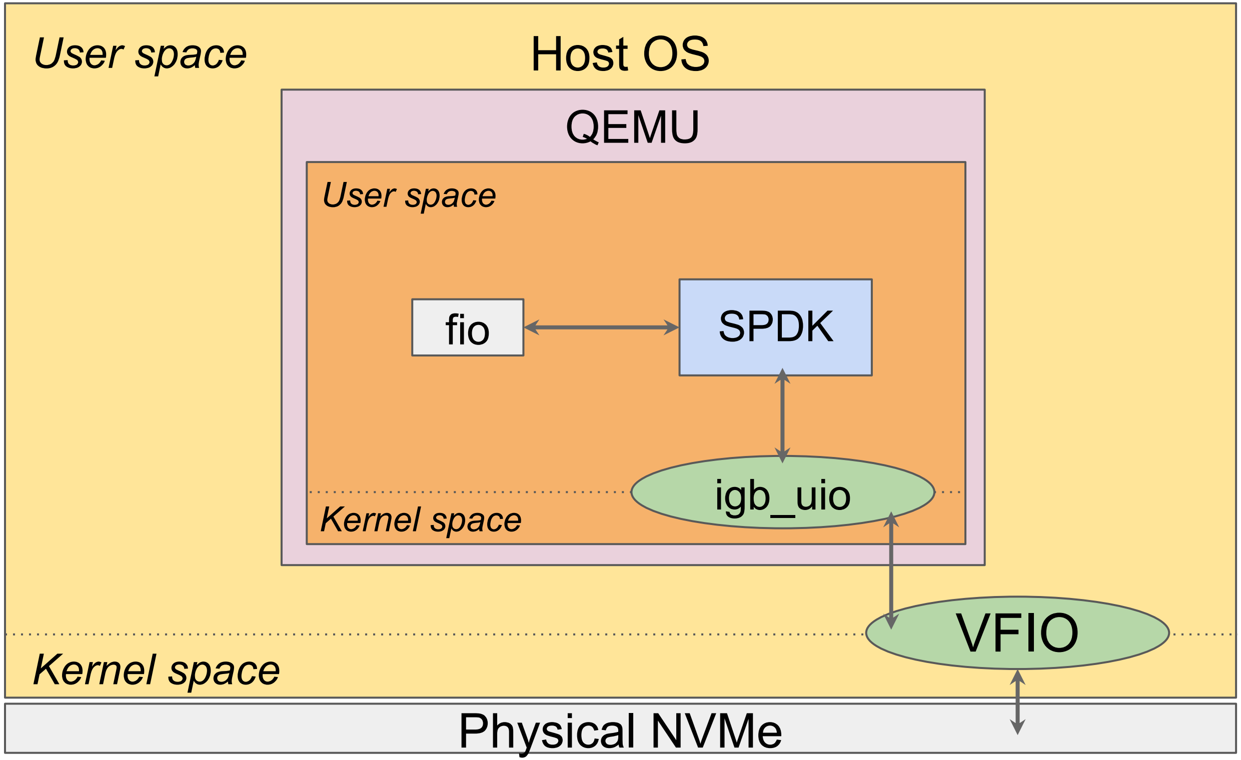
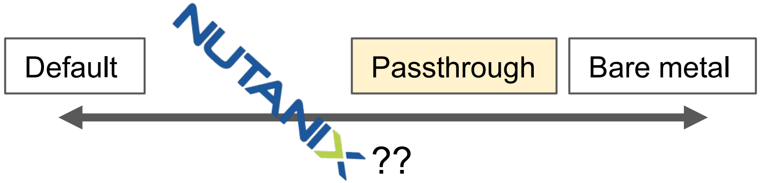
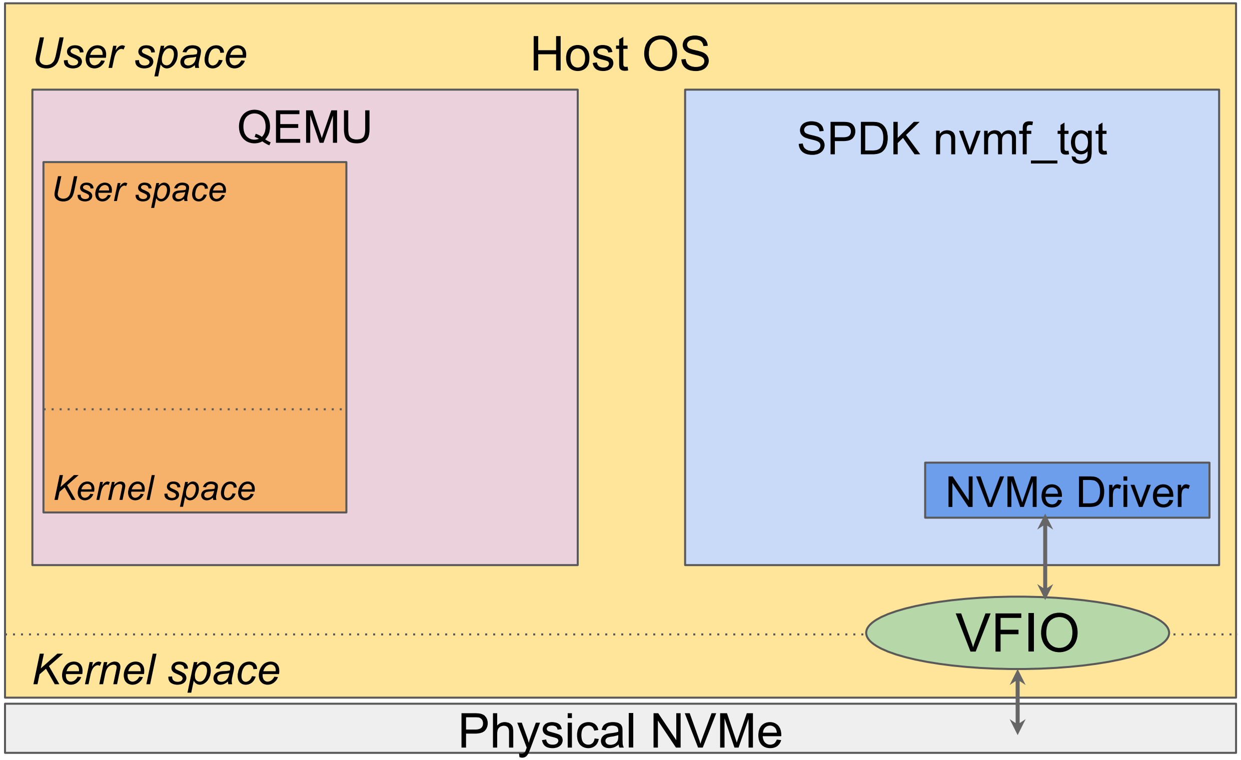




Vfio-user configuration





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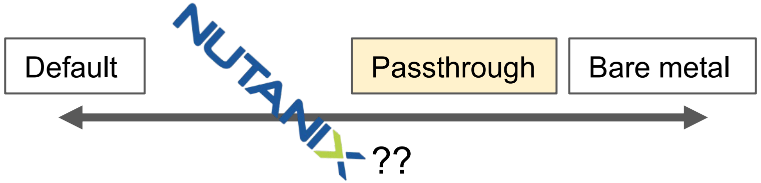

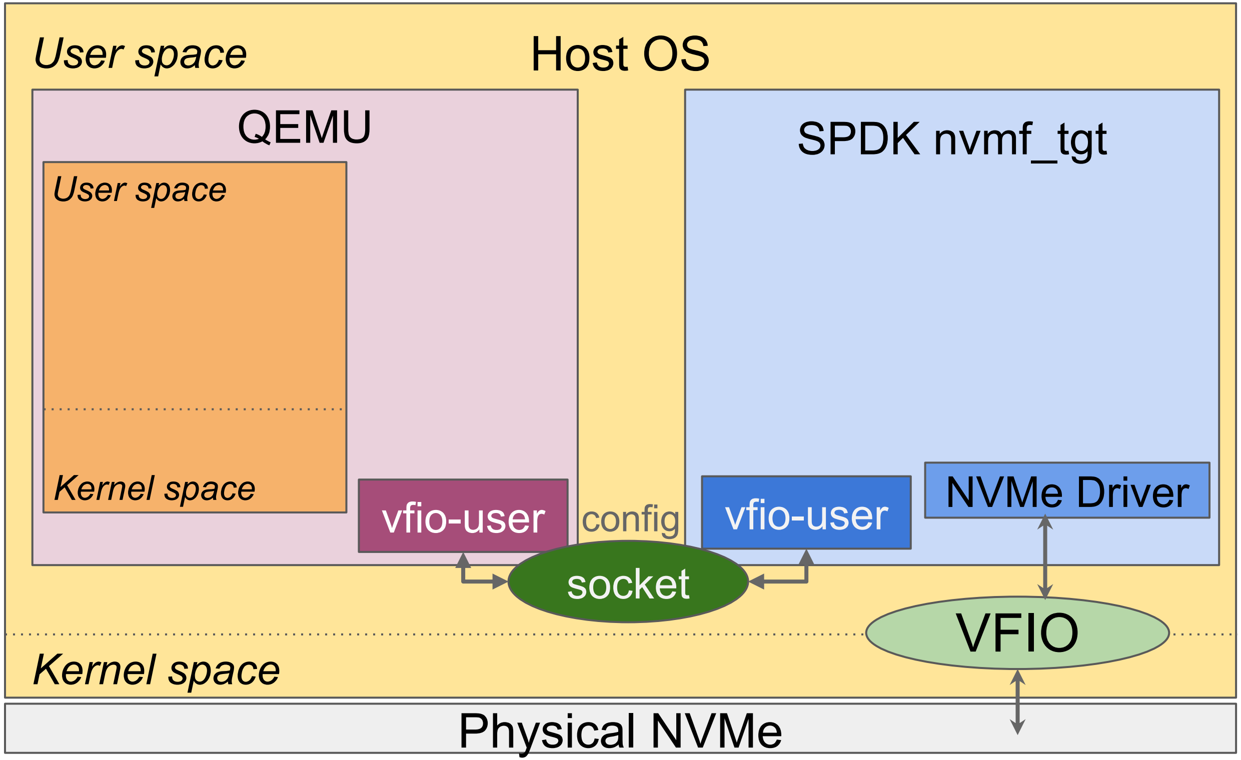

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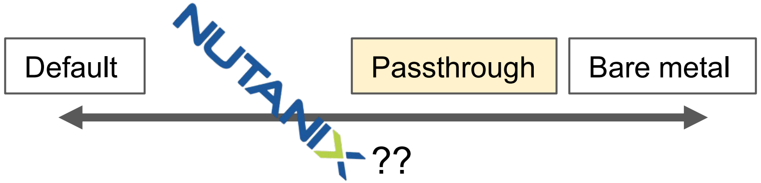

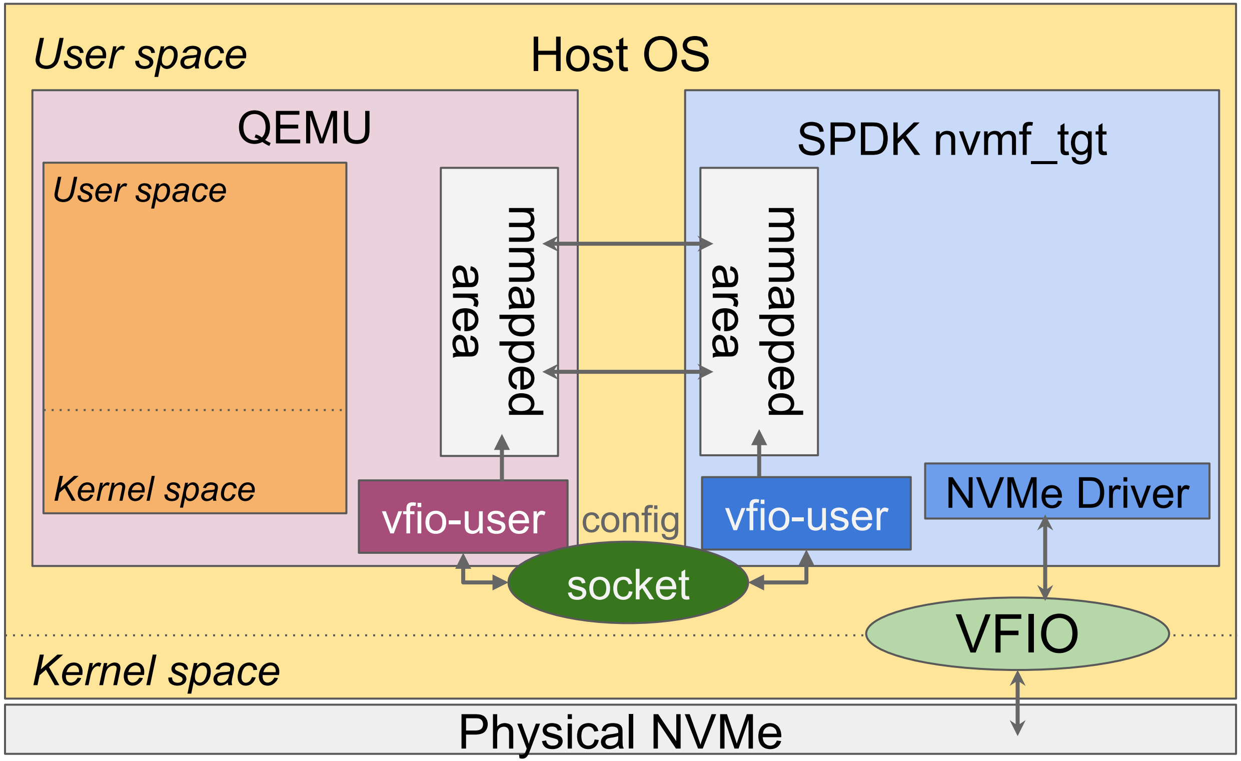

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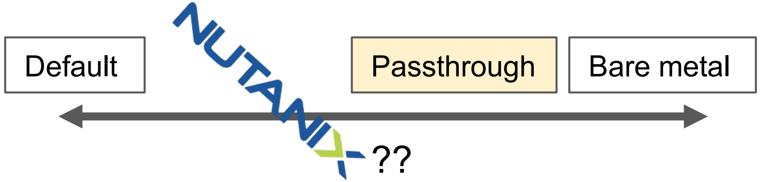

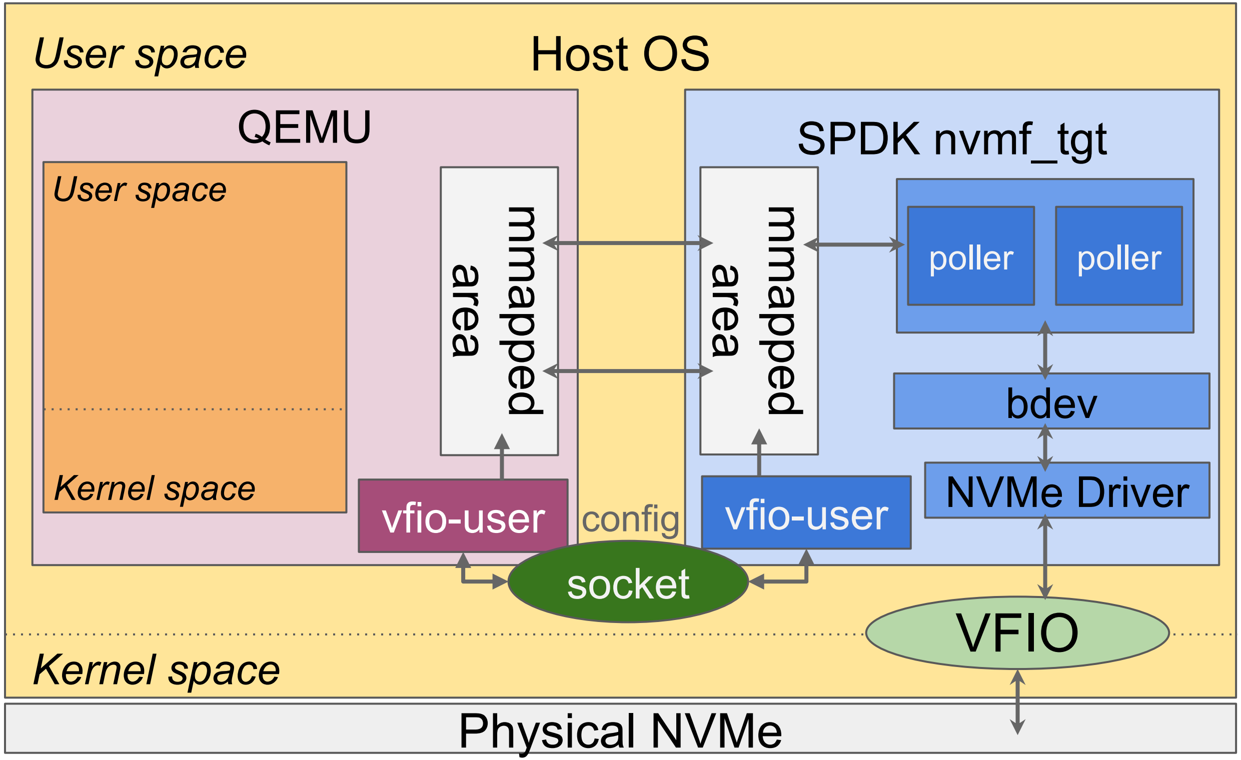

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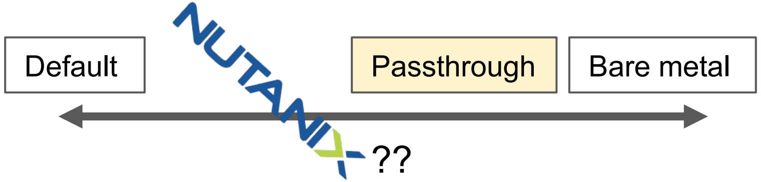
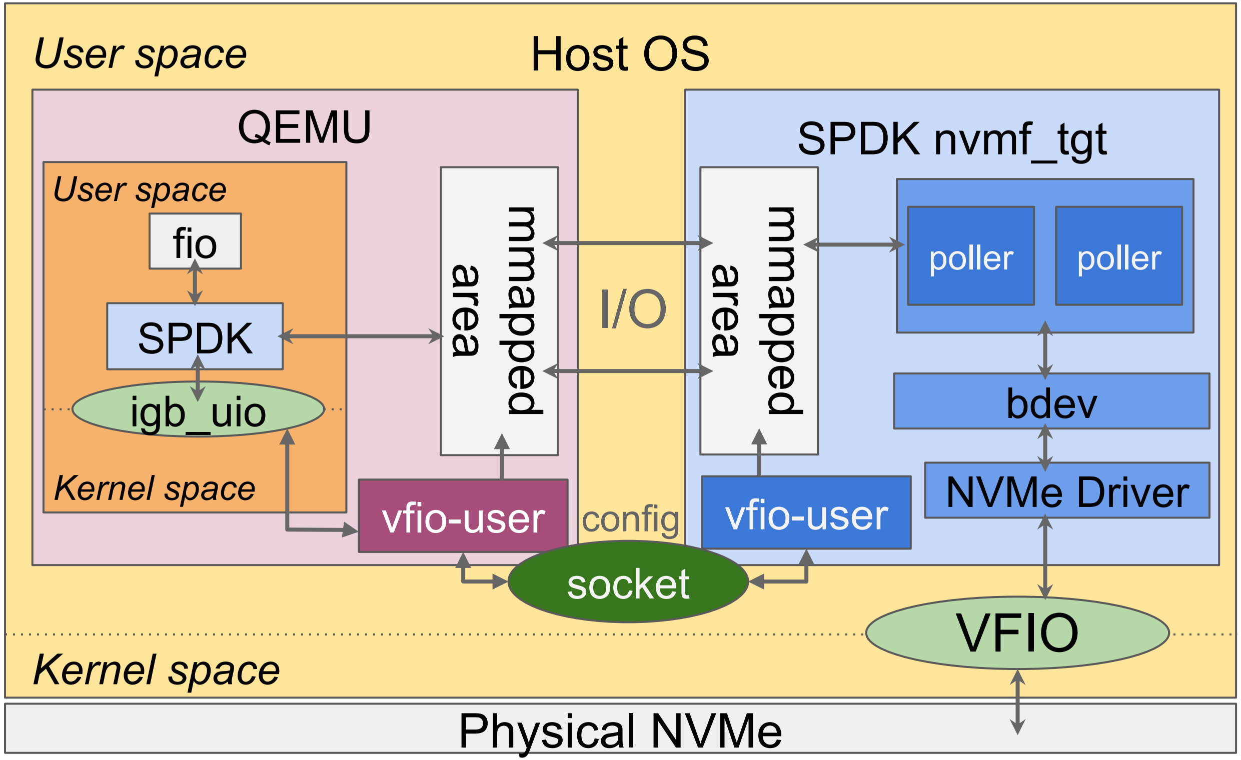
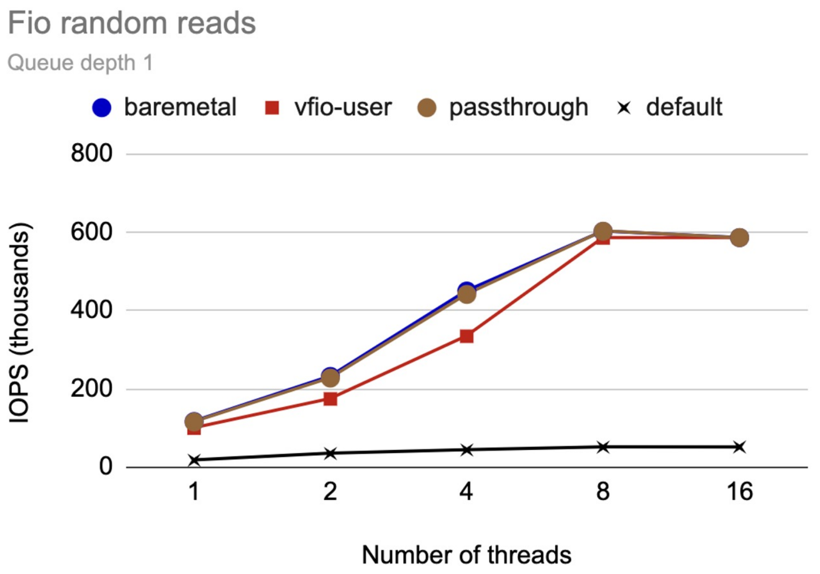


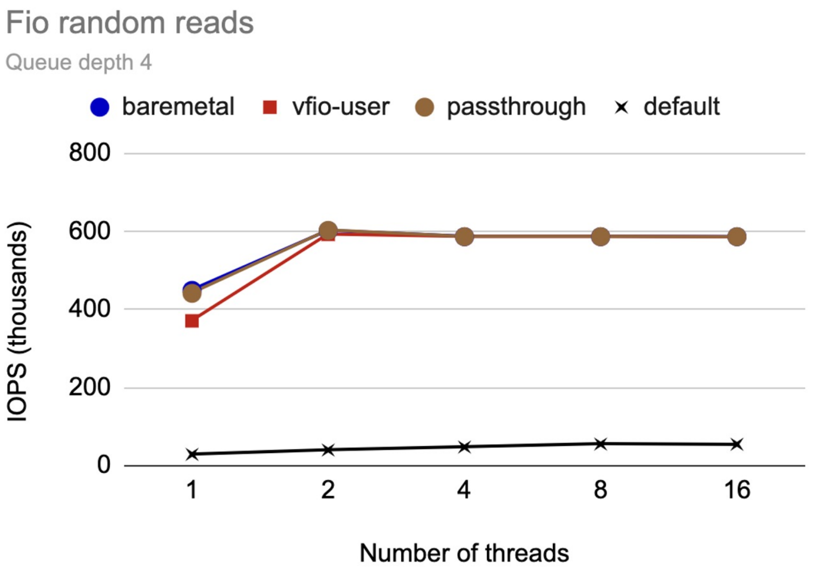


Experimental evaluation

Hardware Specifications	
CPU	36 Core Xeon Gold 6240L @ 2.40 GHz
Memory	768 GiB 3200MHz DDR4 DIMM
SSD	375GiB Dell Express Flash NVMe P4800X

Results: fio random reads





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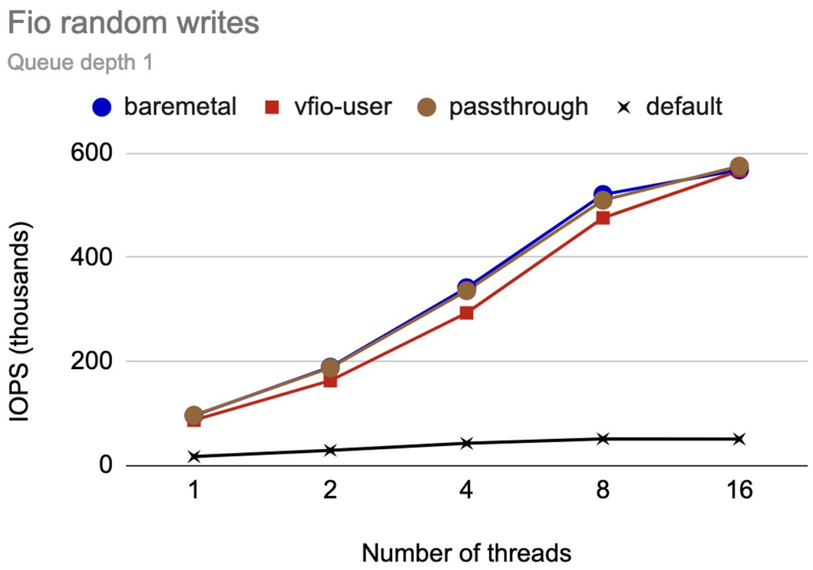
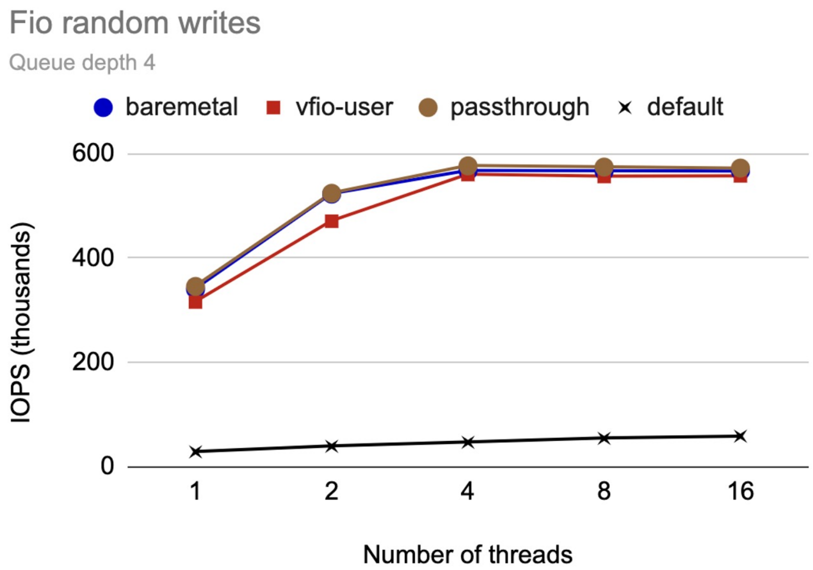
Results: fio random writes





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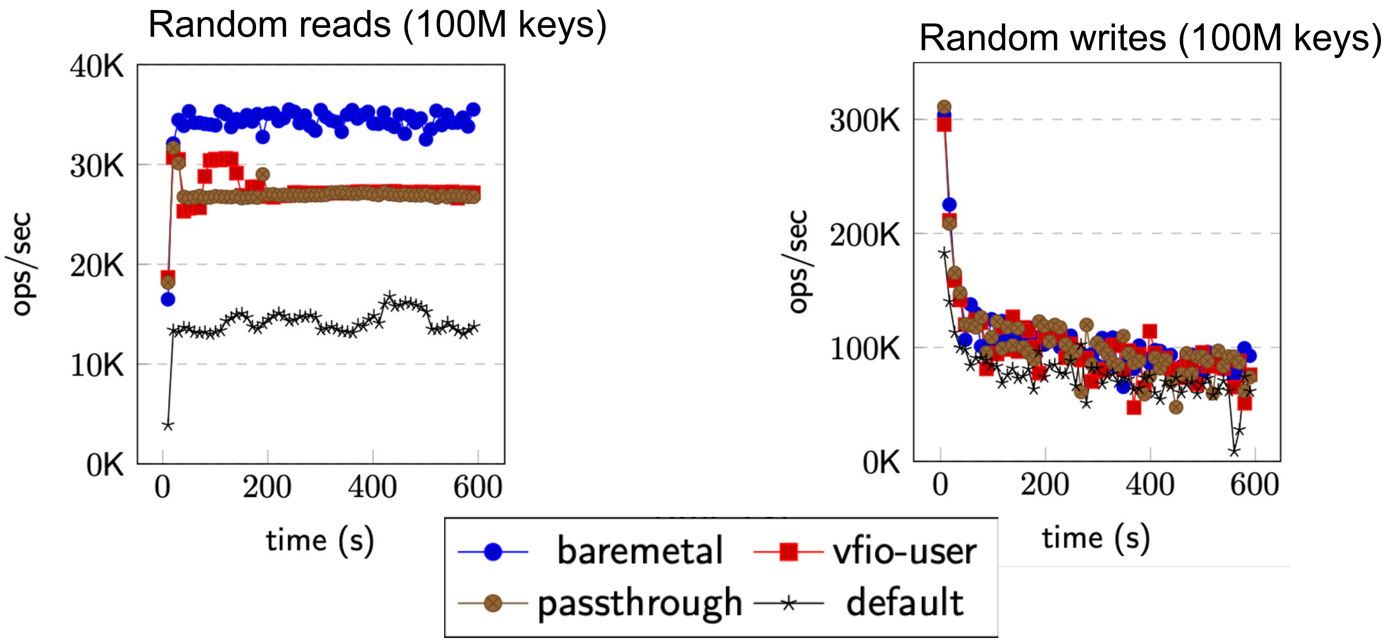
Results: RocksDB benchmarks

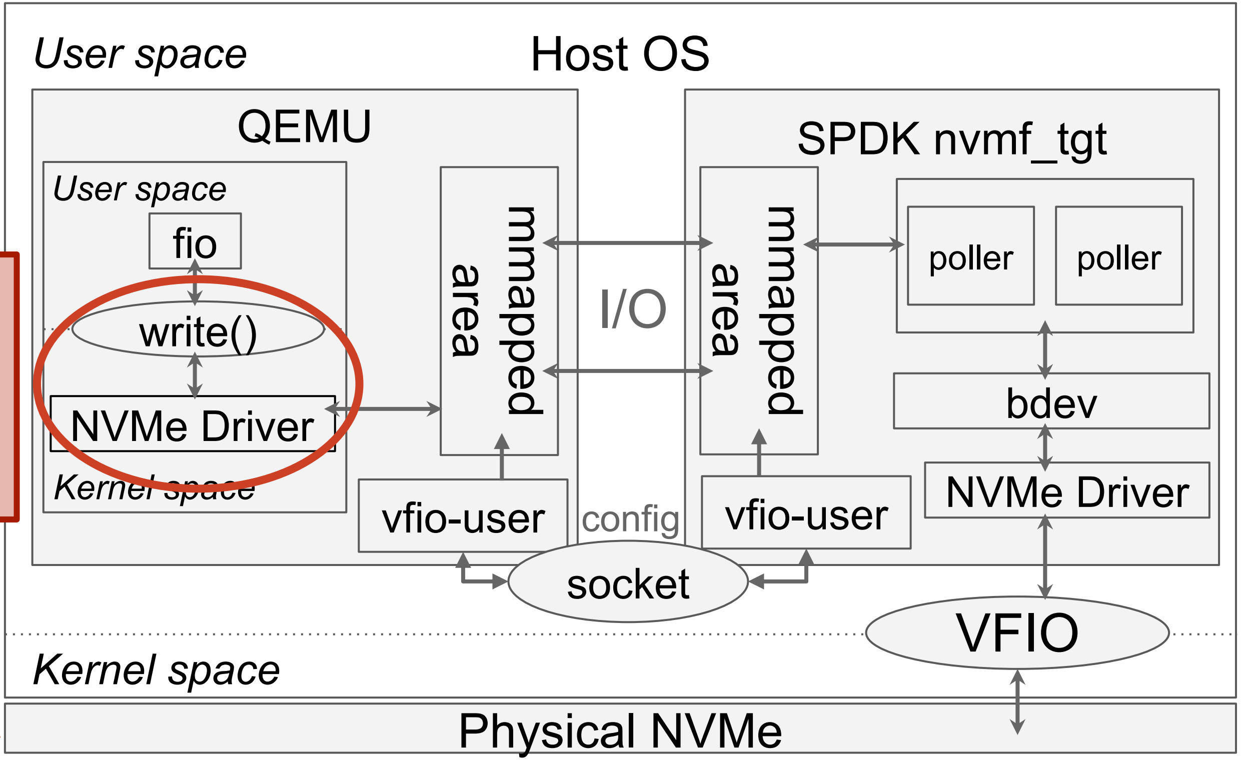


Random reads (100M keys)

Random writes (100M keys)

Layer-by-layer latency measurement

Replaced internal SPDK with synchronous I/O and guest NVMe driver



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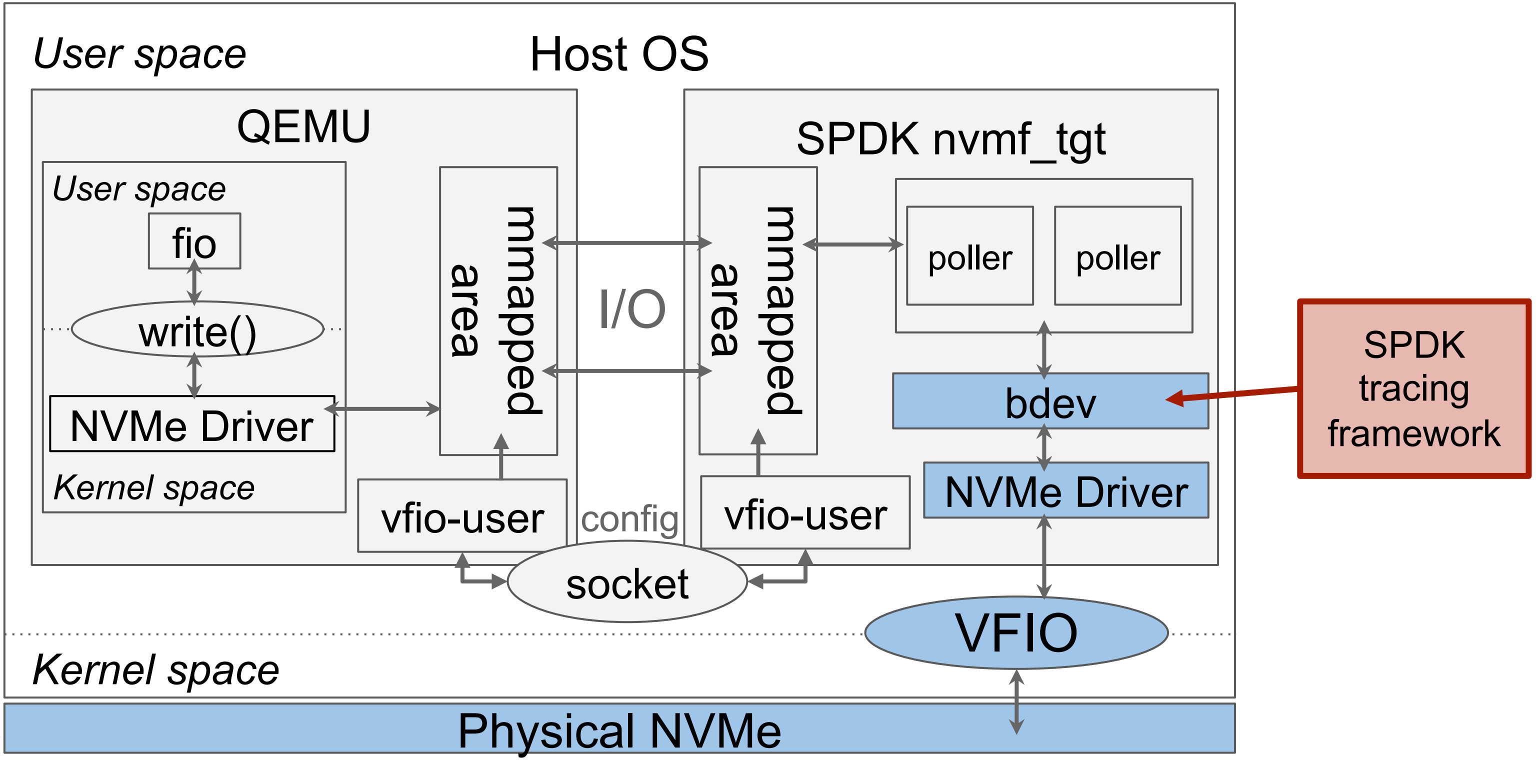

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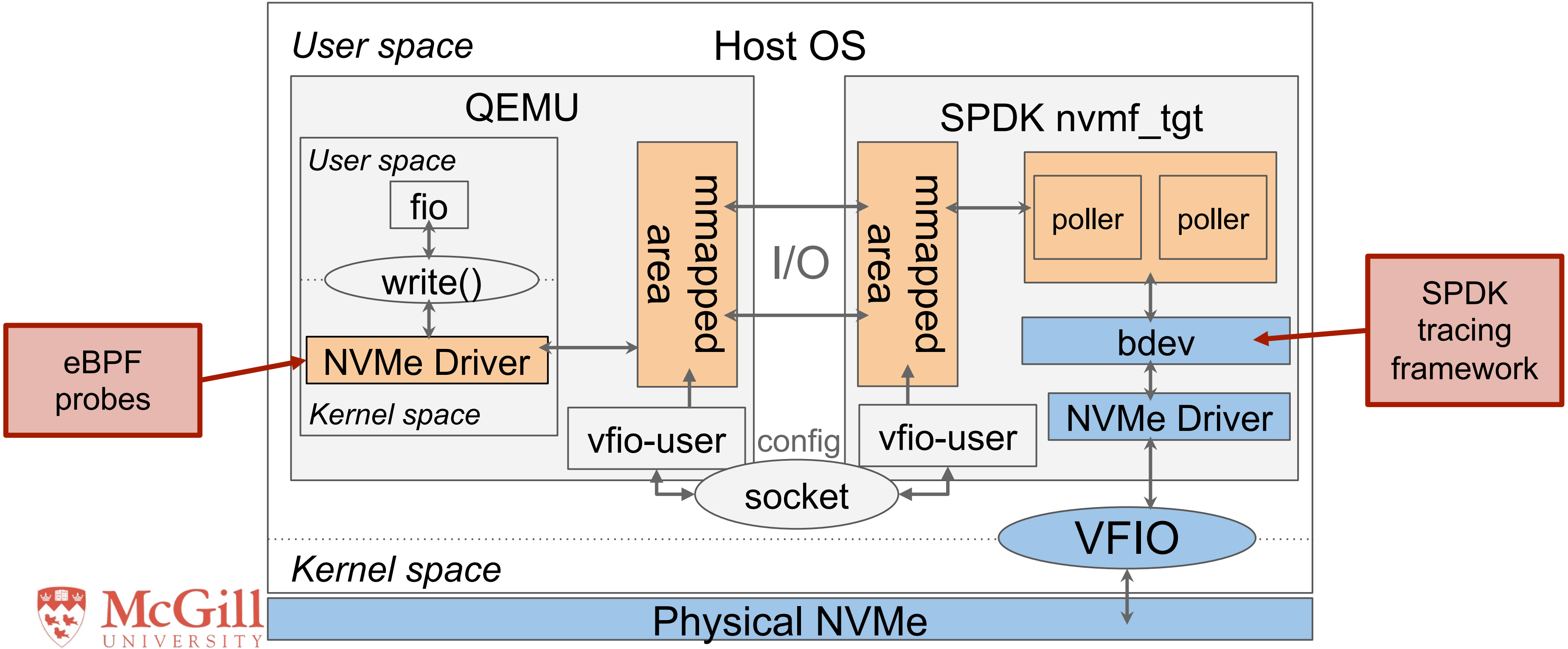

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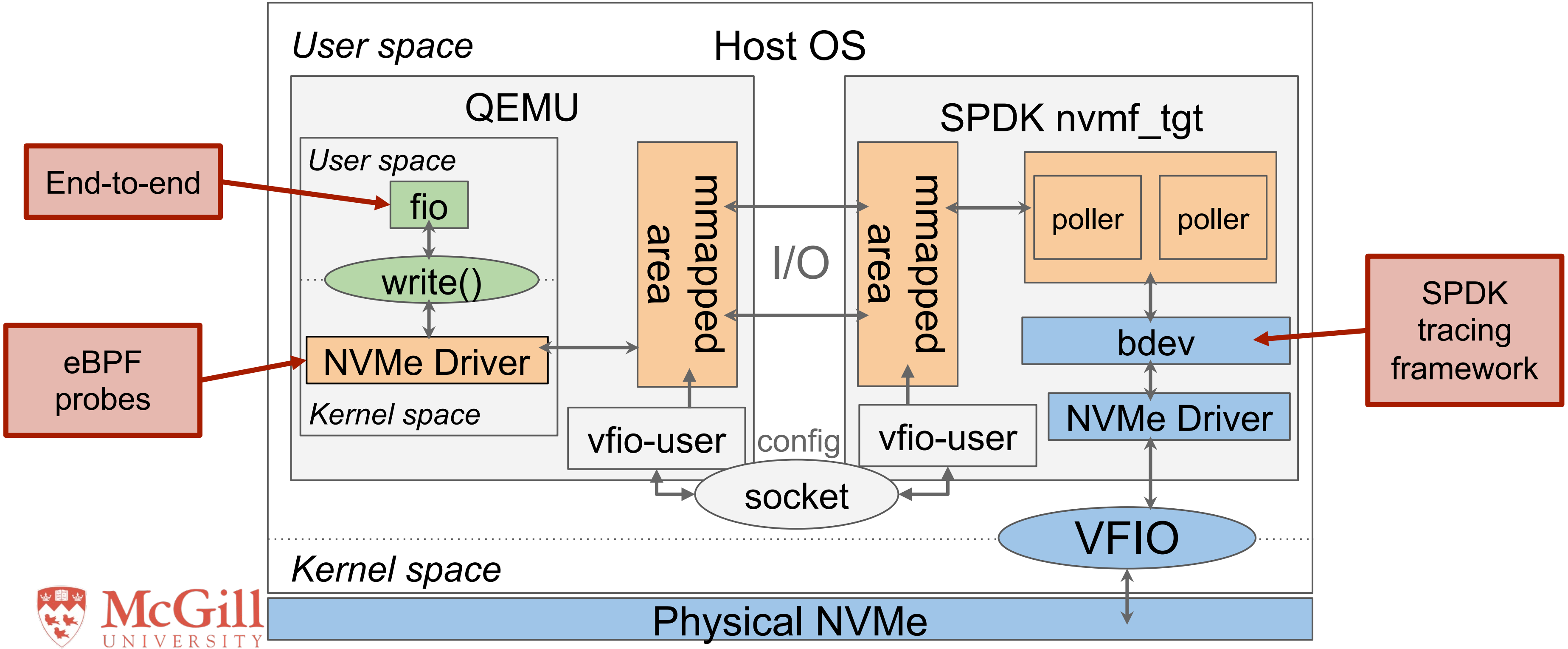
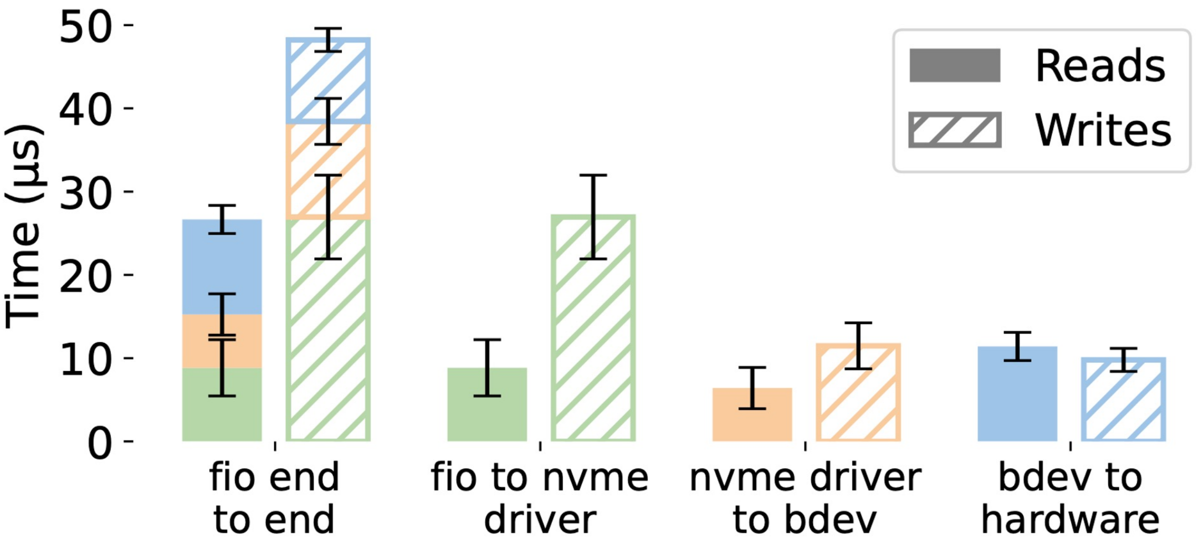
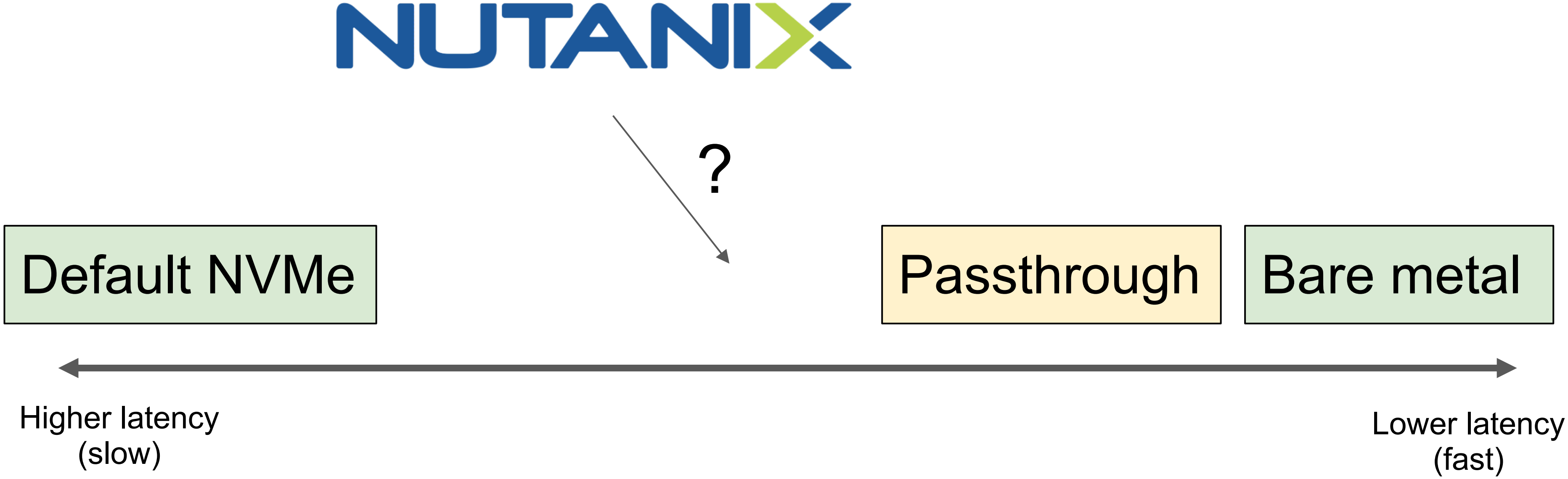


Layer-by-layer latency measurements



Where does vfio-user fit again?



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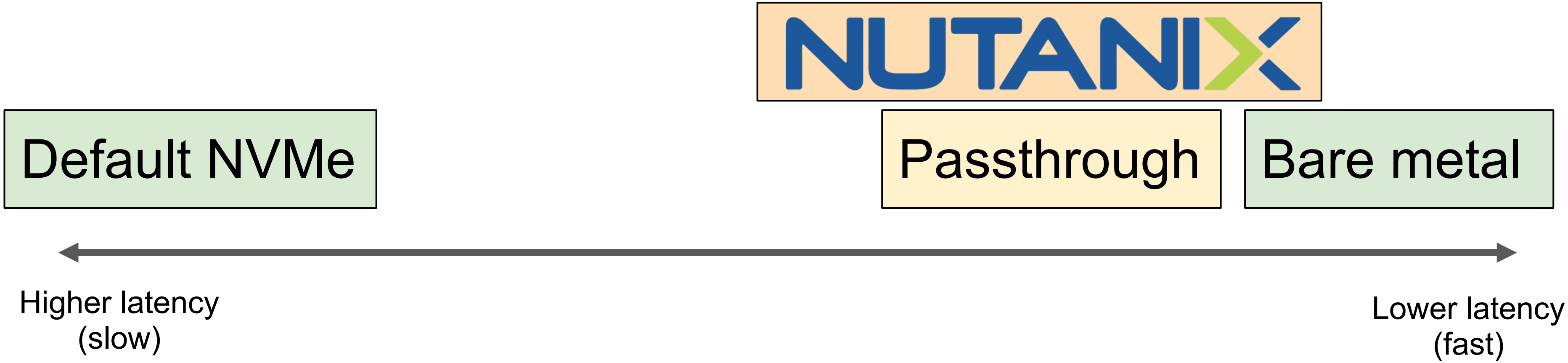
Right about next to Passthrough



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Default NVMe

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Conclusion

- **Vfio-user** appears to have comparable performance to passthrough
- Could be viable for VM storage
- See more benchmarks and analysis in our paper!

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