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HotChips

High-density Multi-tenant Bare-metal Cloud with Memory Expansion SoC and Power Management

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Why Baremetal Cloud and What is X-Dragon?

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1 For security and isolation

2 For multi-tenancy and cost efficiency

3 For single-thread performance

4 For interoperability and manageability

X-Dragon: multi-tenant BM-Guests in same Server

Problems

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There are VM-based cloud, single-tenant bare-metal cloud and BM-Hive(Multi-tenants bare-metal cloud) in Datacenter

Problem1: VM-based Cloud has non-ignorable virtualization overhead, isolation/security concern and limited single thread performance, but good manageability

VM-based Cloud

Legacy Baremetal Cloud

Problem2: Existing bare-metal cloud design for single tenant, lack of manageability and also costly

Xdragon: Design for cloud with multi-tenant, secure, high performance and easy manageable

Service	Security	Isolation	Performance	Density
VM-based cloud	Side-channel and Dos attacks because of resource sharing	Weak isolation because of resource sharing	CPU, Memory, and I/O overhead caused by virtualization	Very high density through server over-provisioning
Single-tenant bare-metal cloud	N/A	Strong isolation due to exclusive access to system	Native performance	Very low density, one user per server, leading to high cost
X-Dragon	No side-channel or Dos attacks due to hardware-based isolation; Protected hardware resources, particularly the firmware	Strong hardware-based isolation	Native CPU and memory performance; para-virtualized I/O with minor overhead	High, 16 BM-Guests per server at most

X-Dragon High Level View in Cloud

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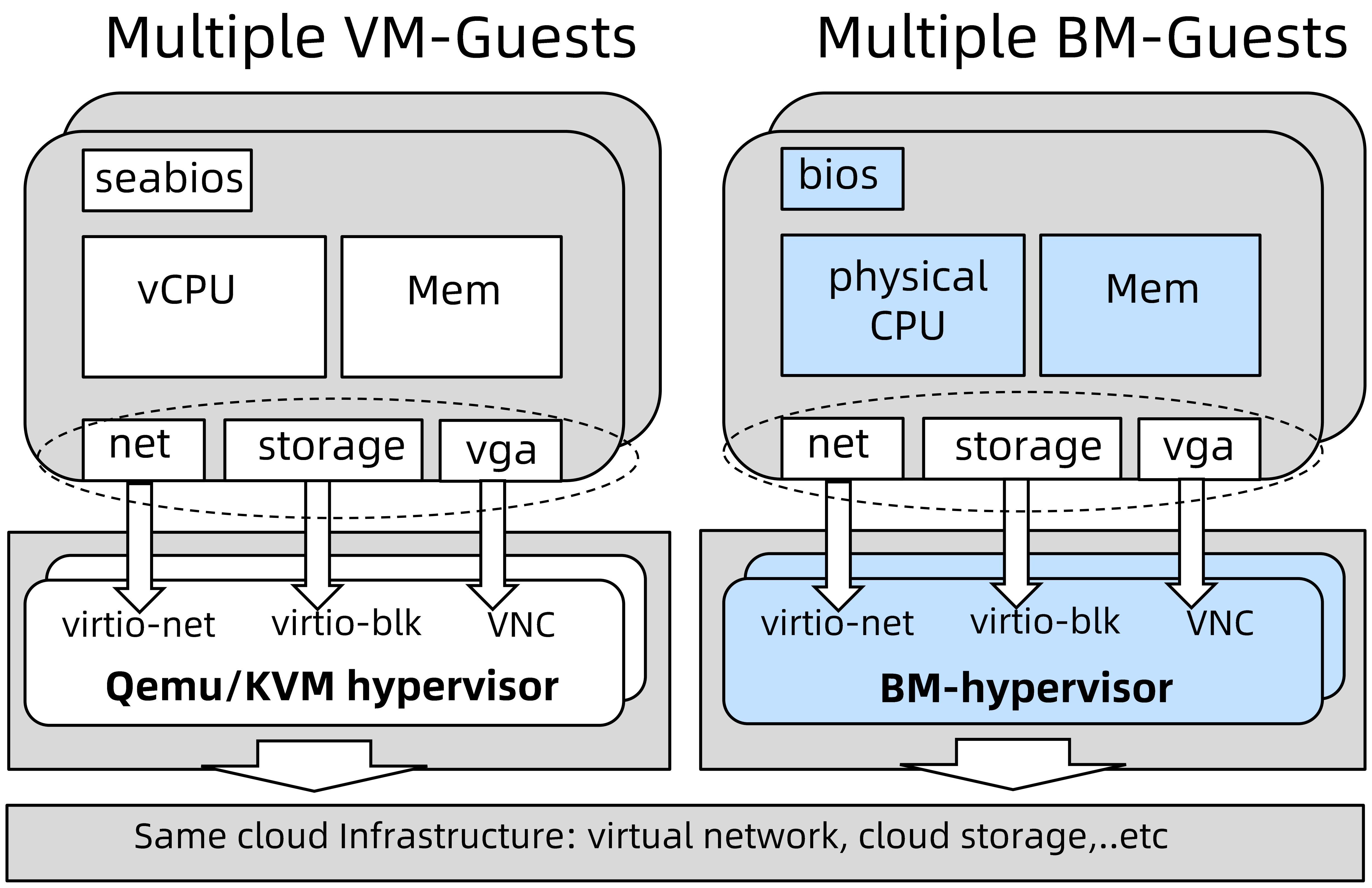

KVM vs X-Dragon

- **Same cloud infrastructure**
- **Same tools to manage**
- **Both Multi-tenants**
- **More secure and selectable bare-metal performance**

X-Dragon System Architecture

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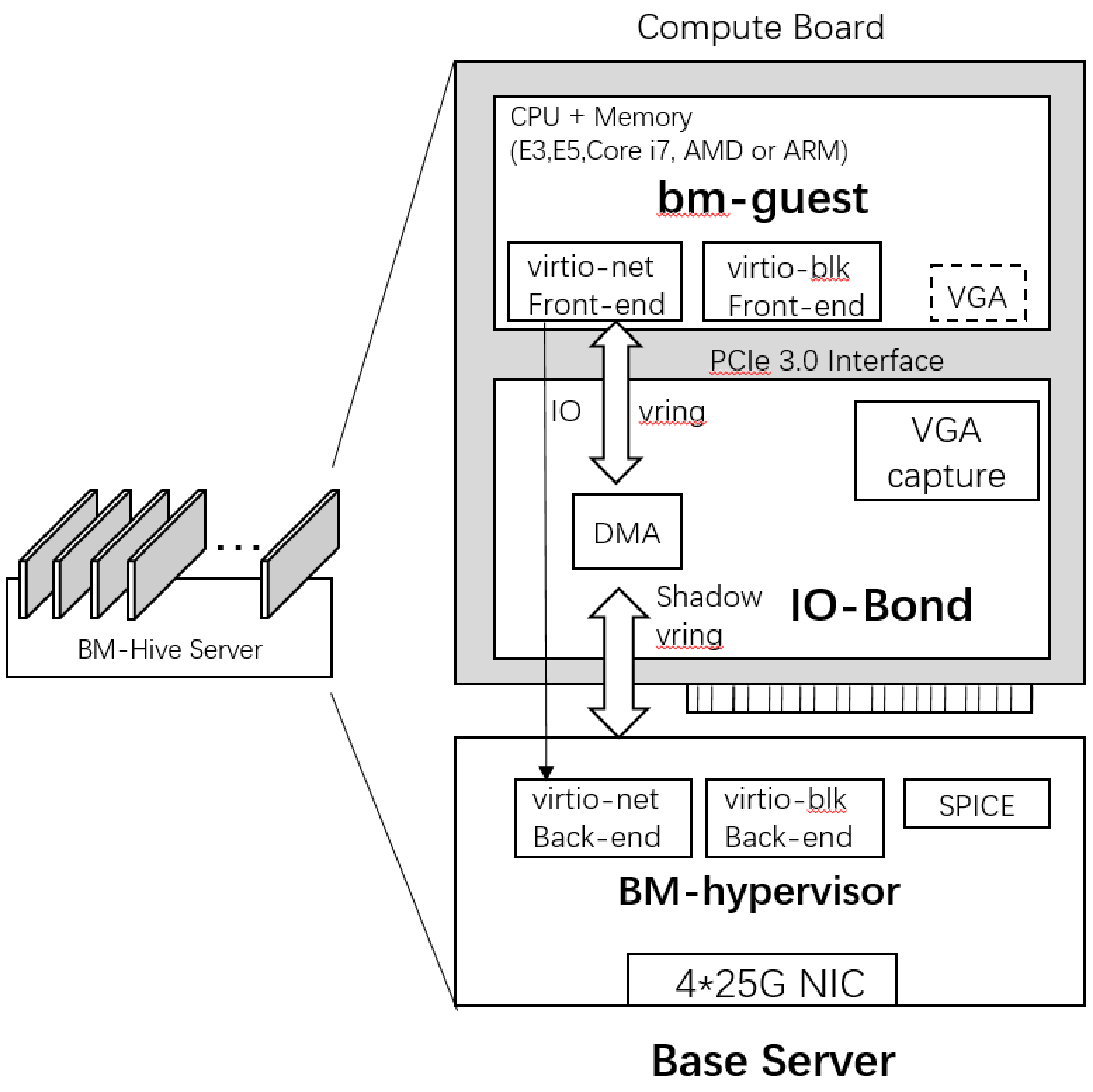

1 **Compute Boards + Base Server**

2 **Hardware implementation of virtio devices**

3 **Custom backend: BM-Hypervisor**

X-Dragon: IO Bond and Backend

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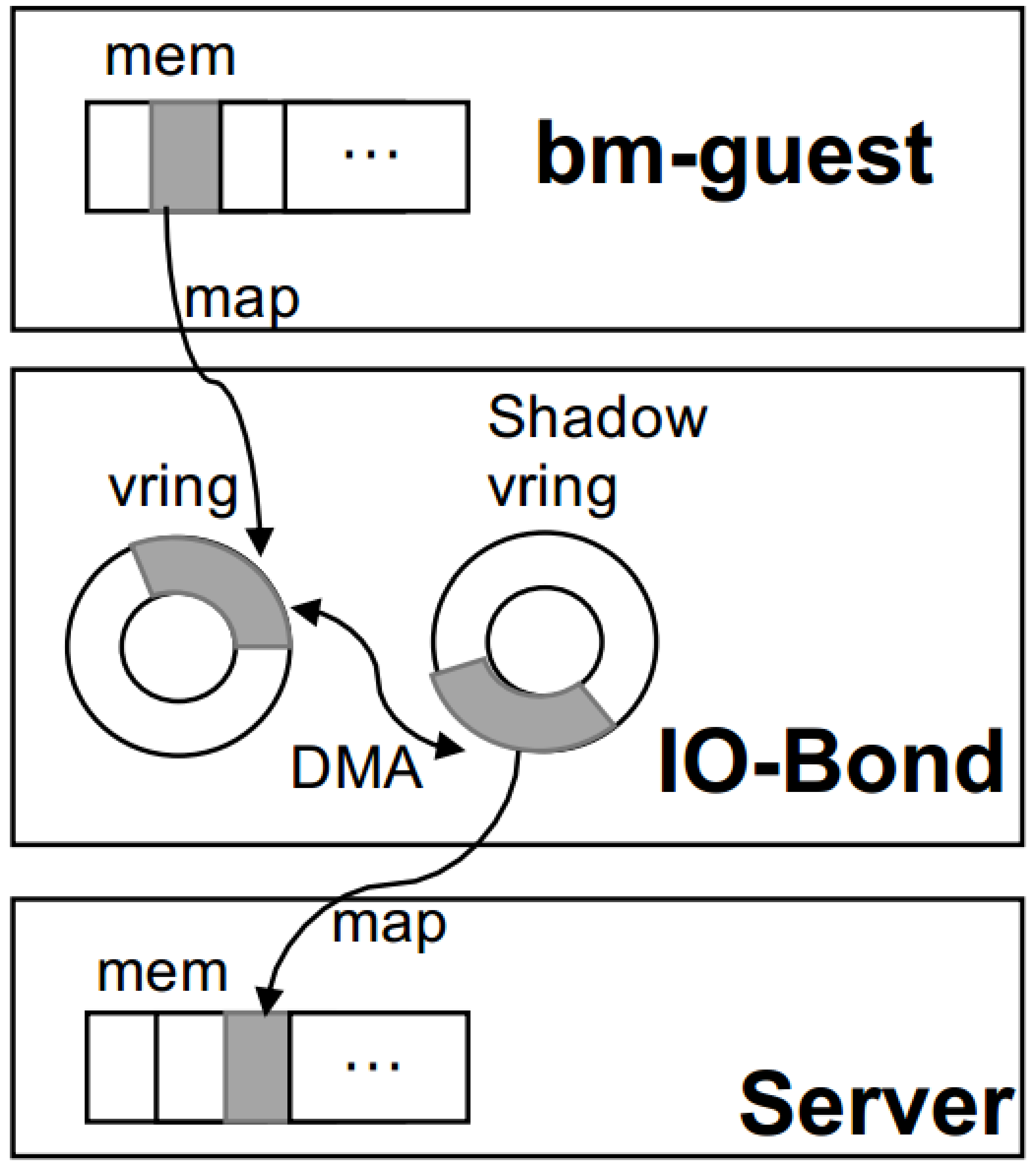

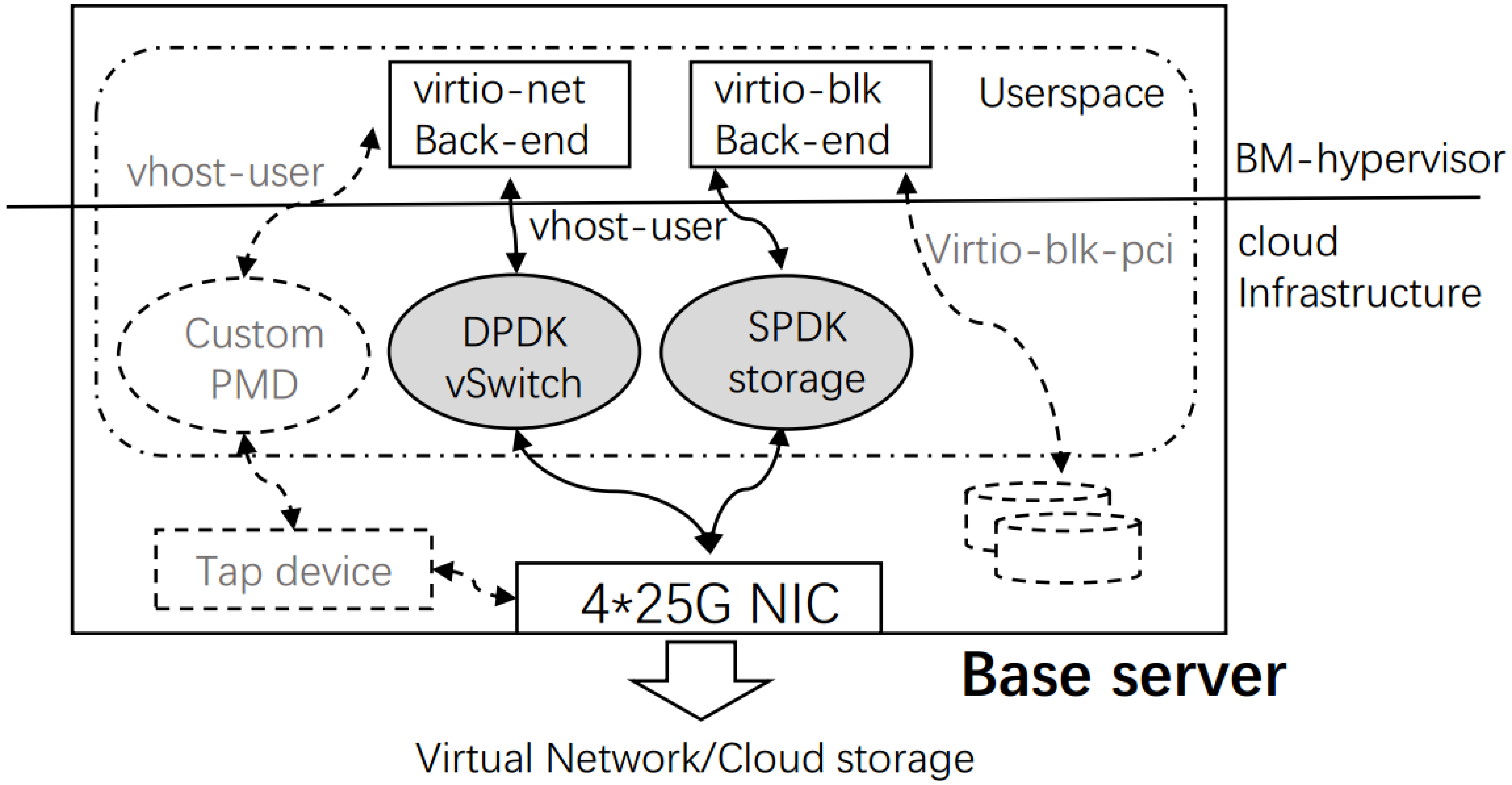

Shadow Ring buffer design

Transfer data between computing board and backend base server

BM-Hypervisor design

Emulate virtio-devices, and connect into existing cloud infrastructure

Evaluation: CPU/Mem/IO performance

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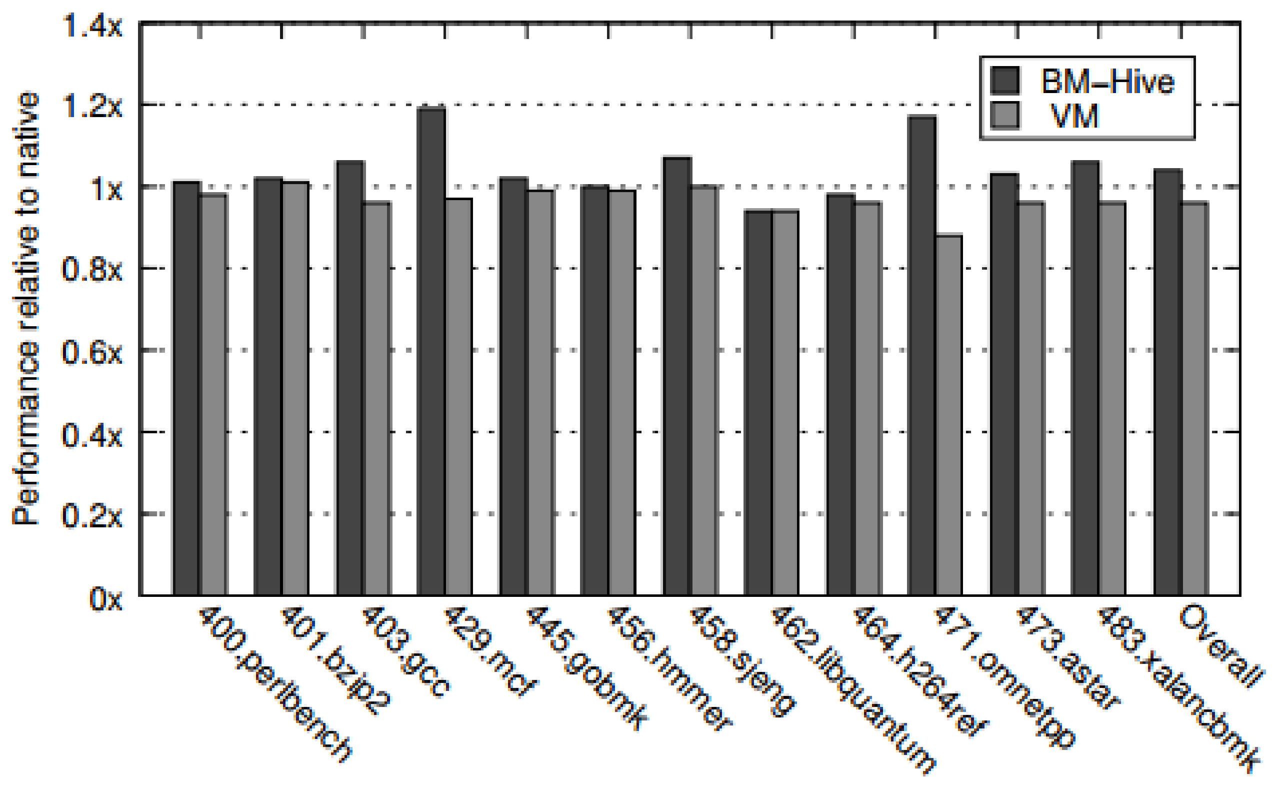

Figure 7. CPU performance by SPEC CPU2006

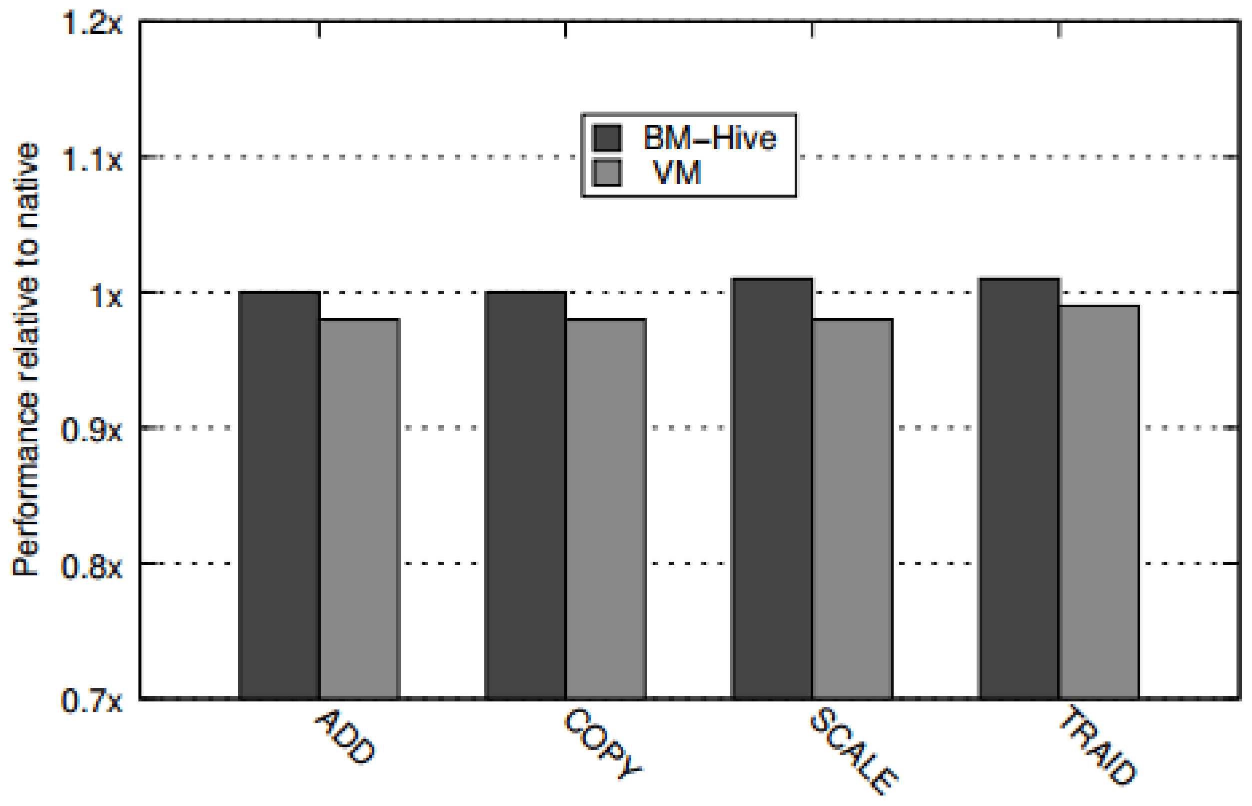

Figure 8. Memory bandwidth by STREAM multi-thread

- X-Dragon BM-Guest vs Native vs VM: BM-Guests are slightly better performance than VM
- Memory bandwidth： BM-Guests are same as Native. VM 98% of BM-Guests under load
- Network PPS: Same PPS rate, however more implied volatility.
- Latency: Same in application level, longer path then DPDK bypass-kernel testing
- Storage: substantially better than VM from latency and long tail.

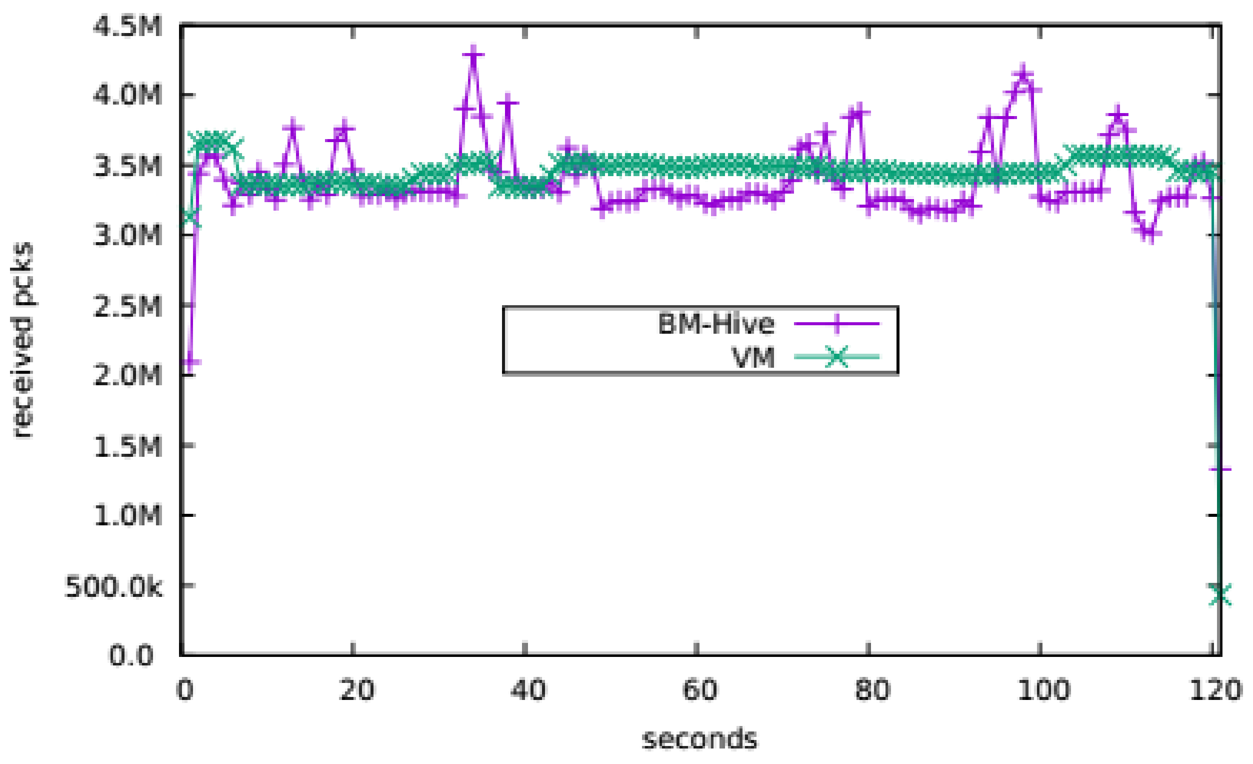

Figure 9. UDP packet receive rate

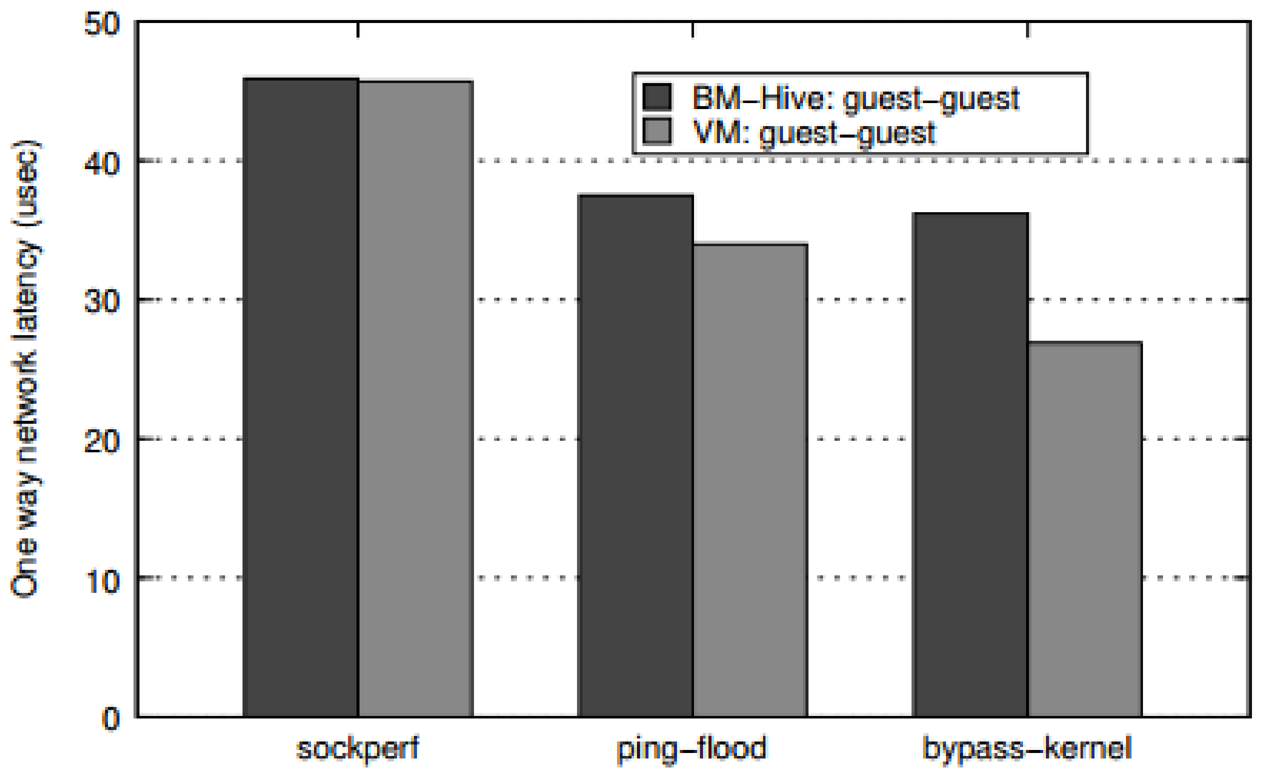

Figure 10. UDP and ping latency

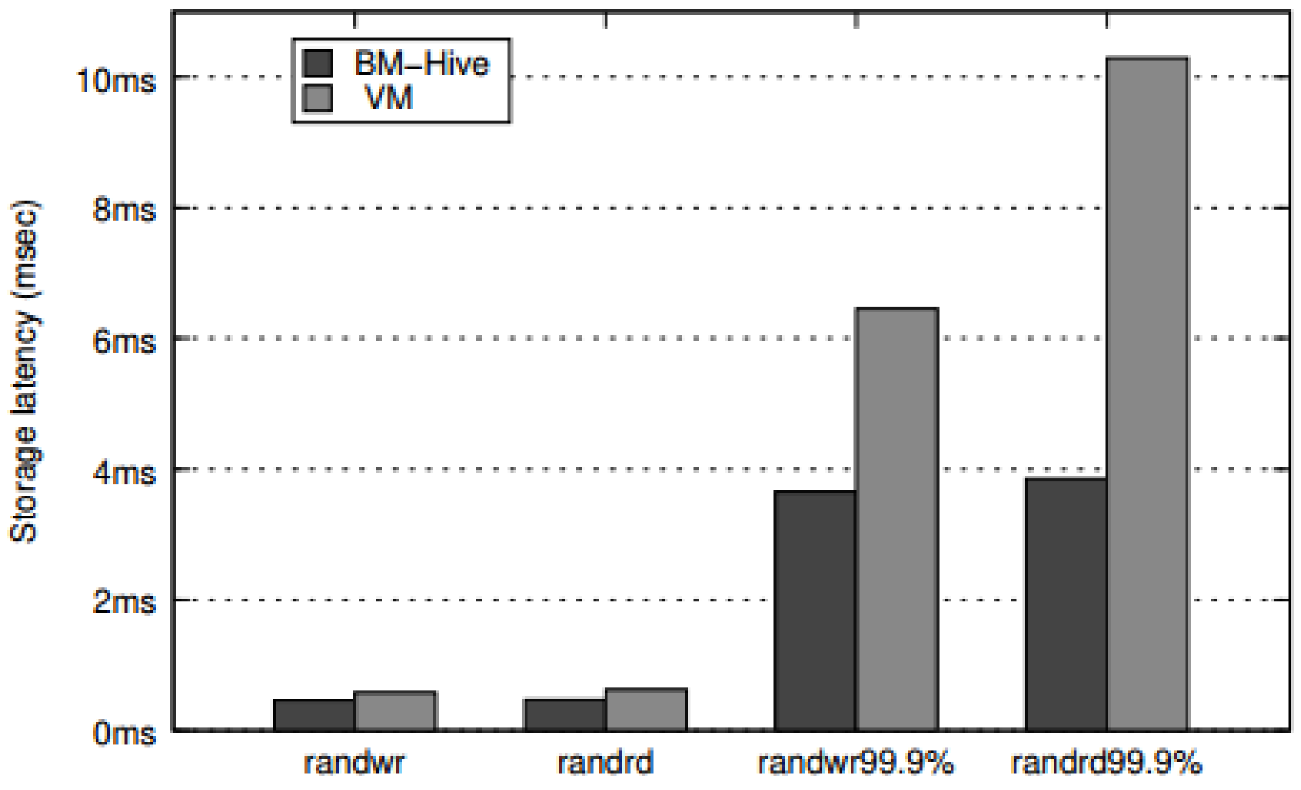

Figure 11. Storage I/O latency

Evaluation: Real business

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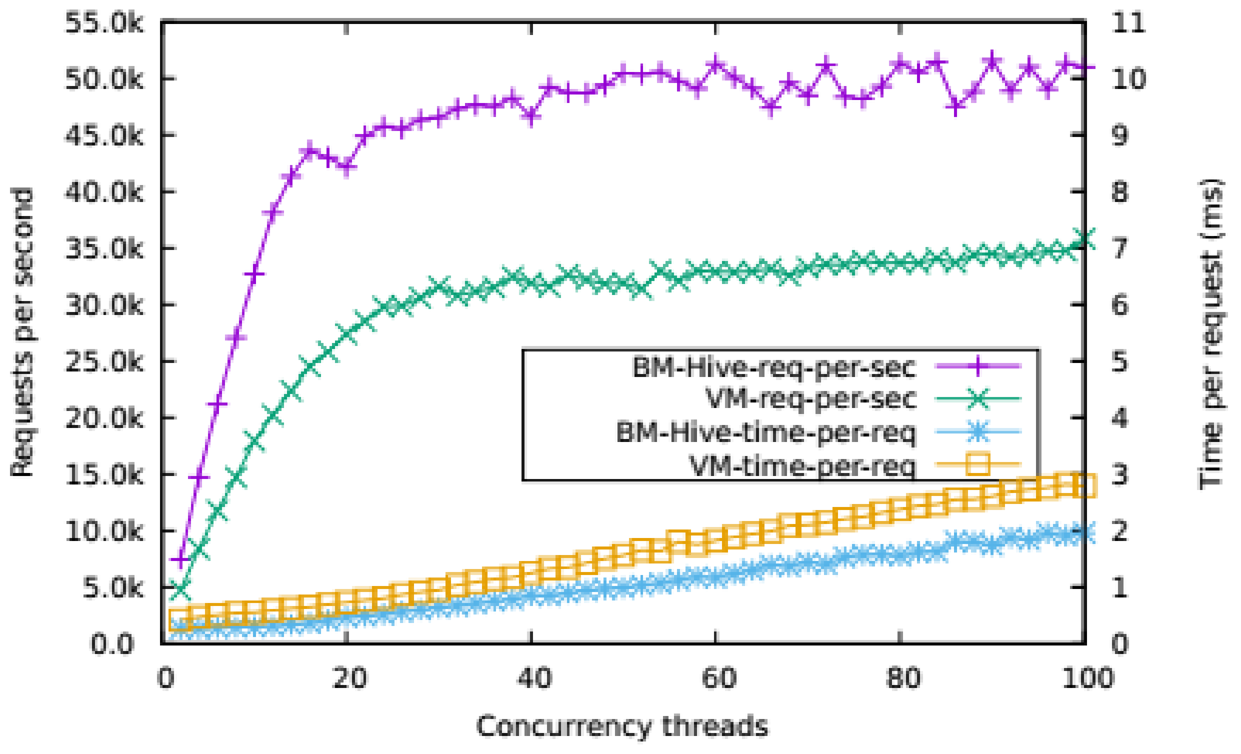

Figure 12. NGINX

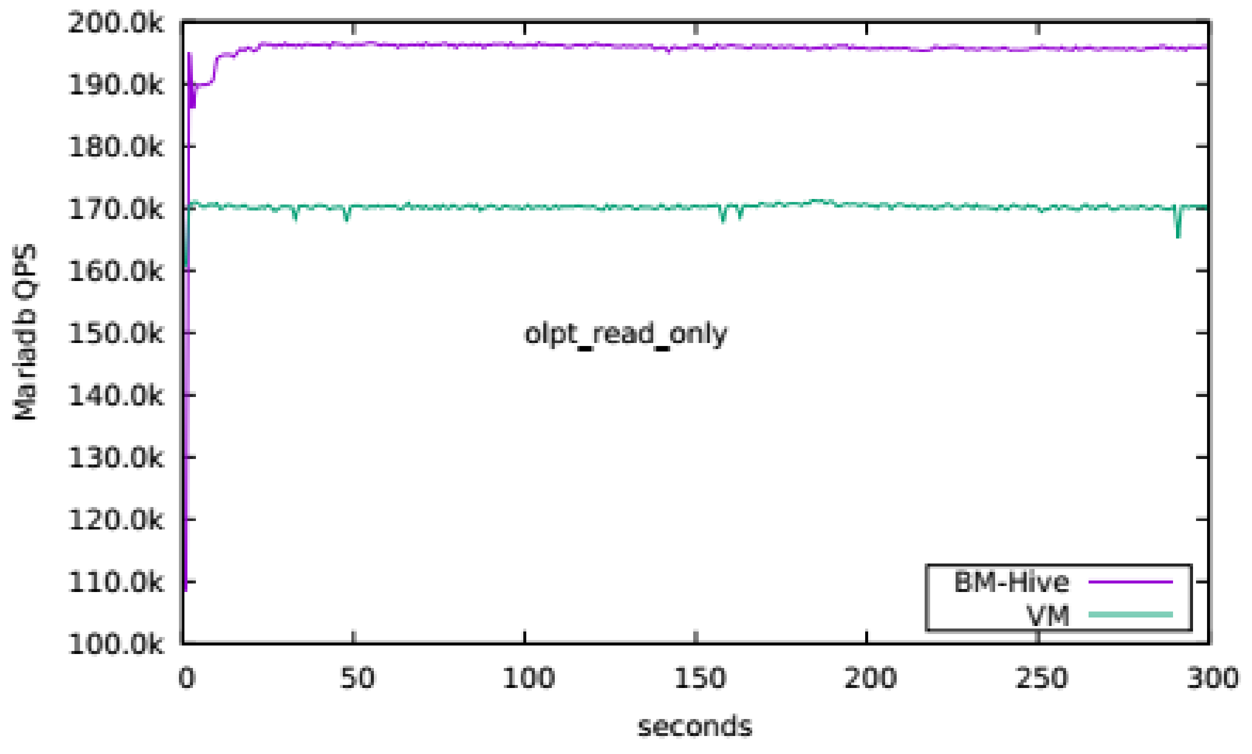

Figure 13. MariaDB ready-only

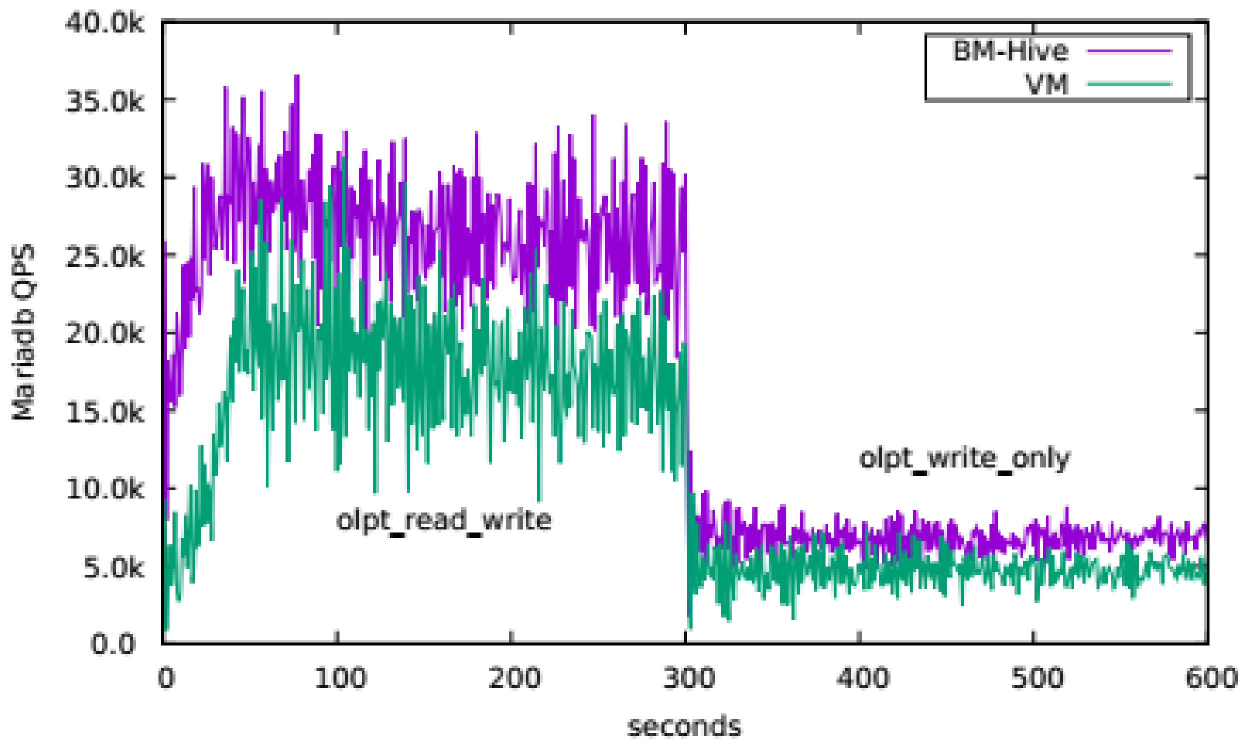

Figure 14. MariaDB rd/wr and wr-only

- Nginx
- MariaDB
- Redis

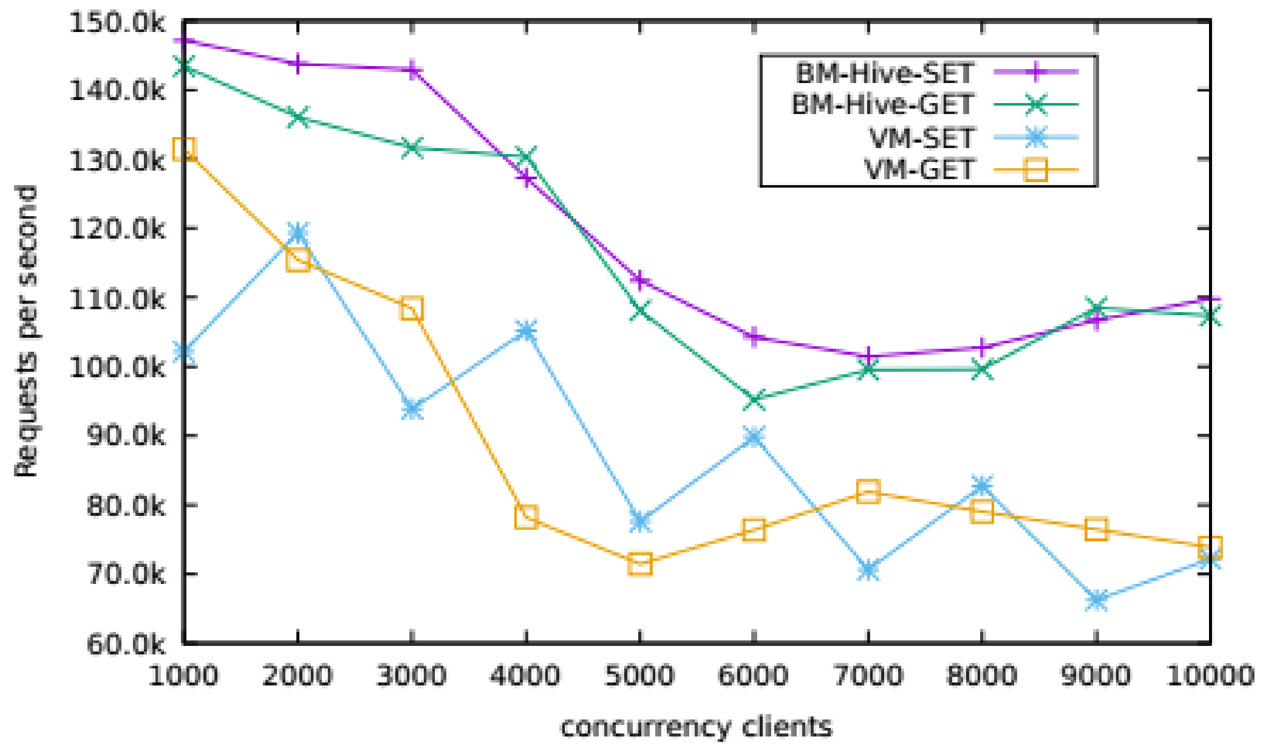

Figure 15. Redis with varying clients

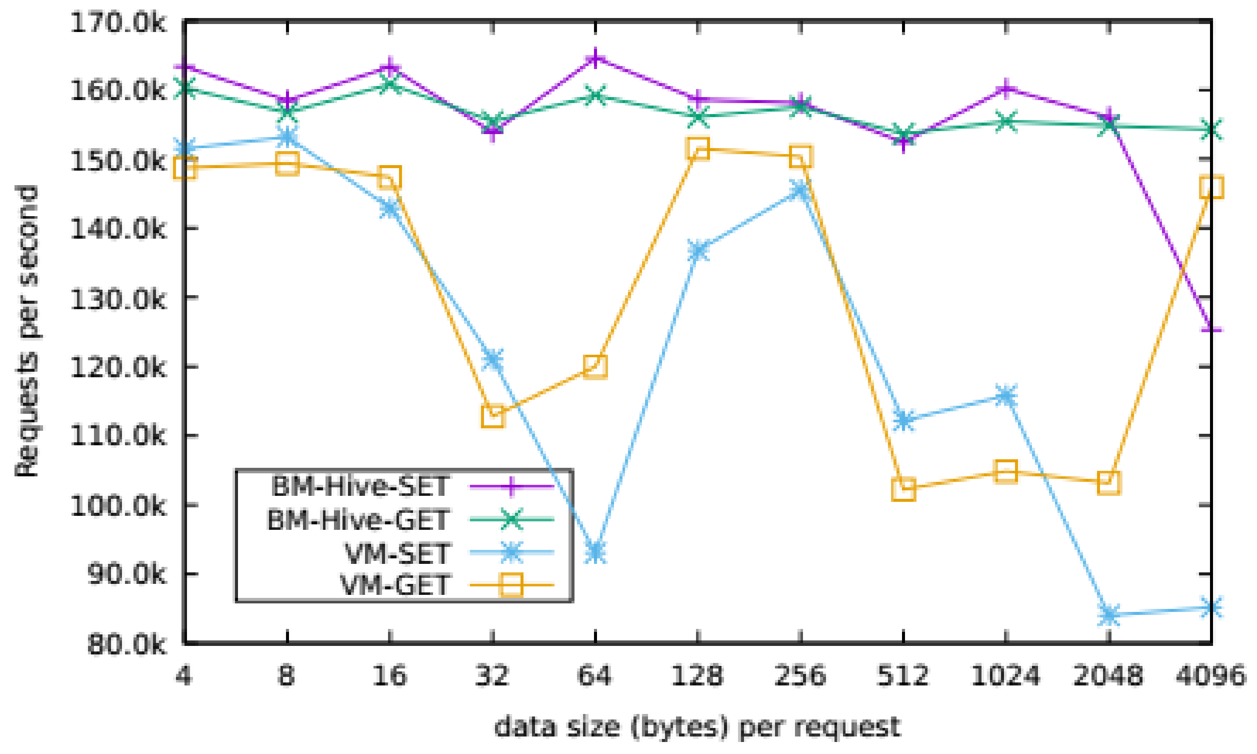

Figure 16. Redis with varying data size

X-Dragon BM guest performs substantially better than the virtualization-based cloud service for the popular applications used in the cloud

X-Dragon based Infrastructure Enhancement

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1 Memory Pool

2 Cloud App Aware Power Management

IaaS TCO optimization and new usage models enabling

Memory Pool

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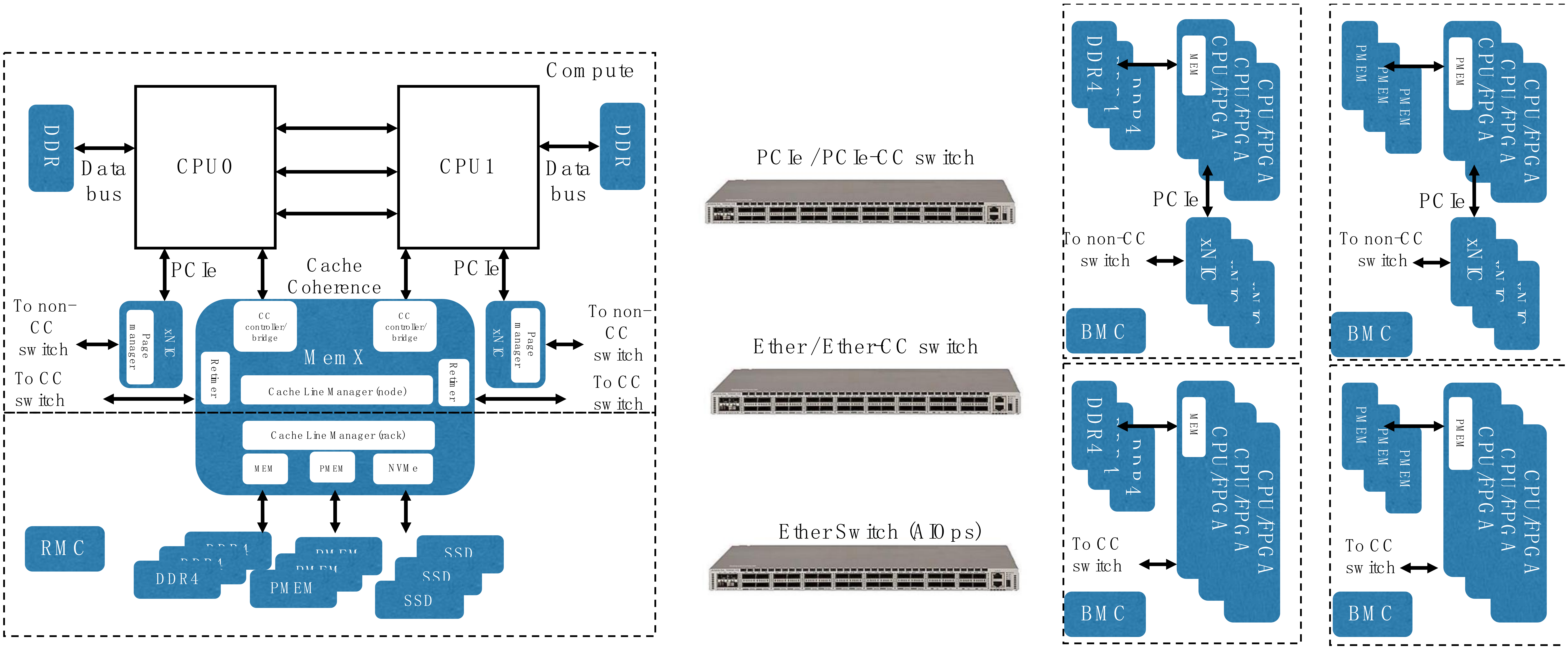

Rack/Local Pool

Switch Fabric

Remote Pool

ROI Analysis

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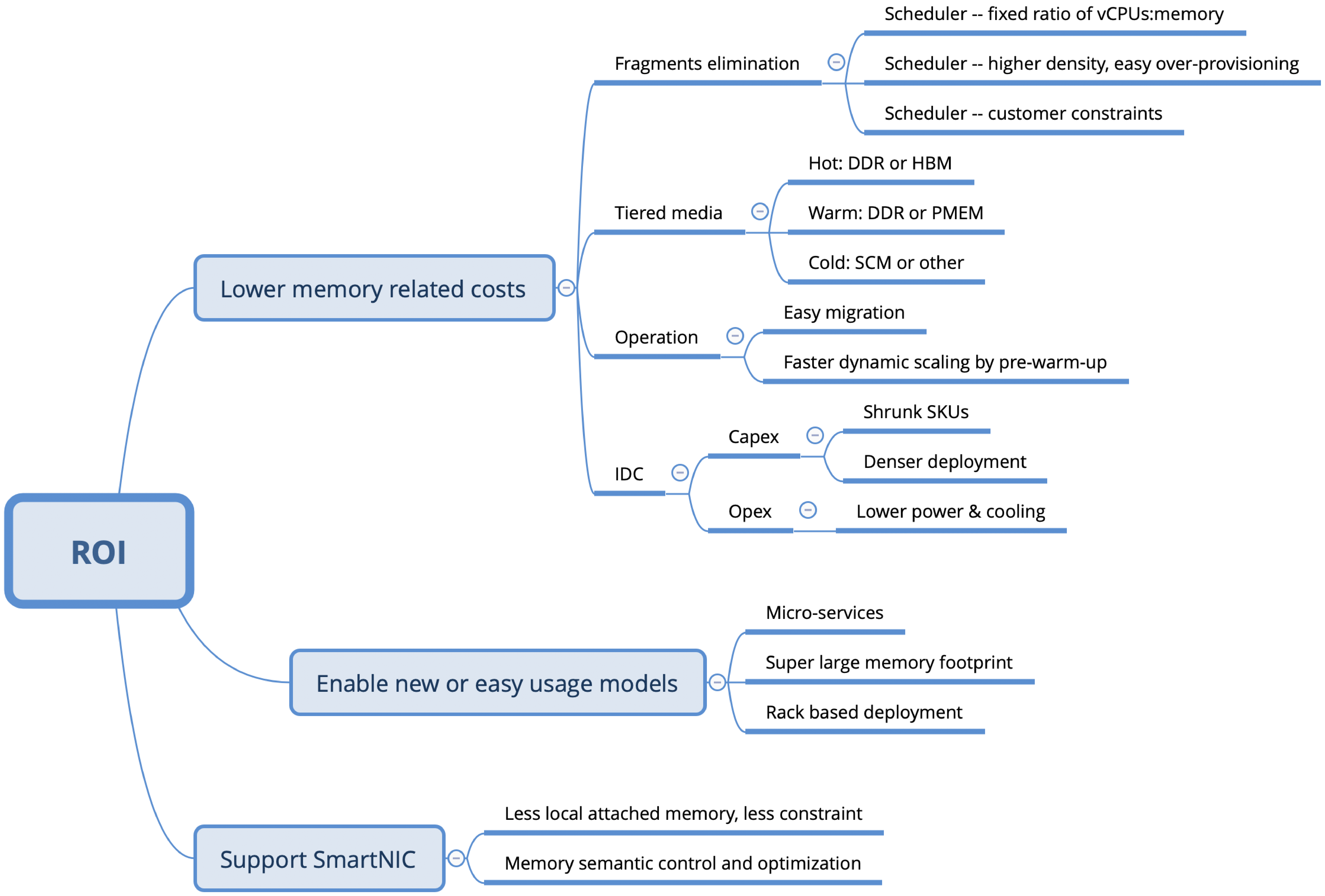
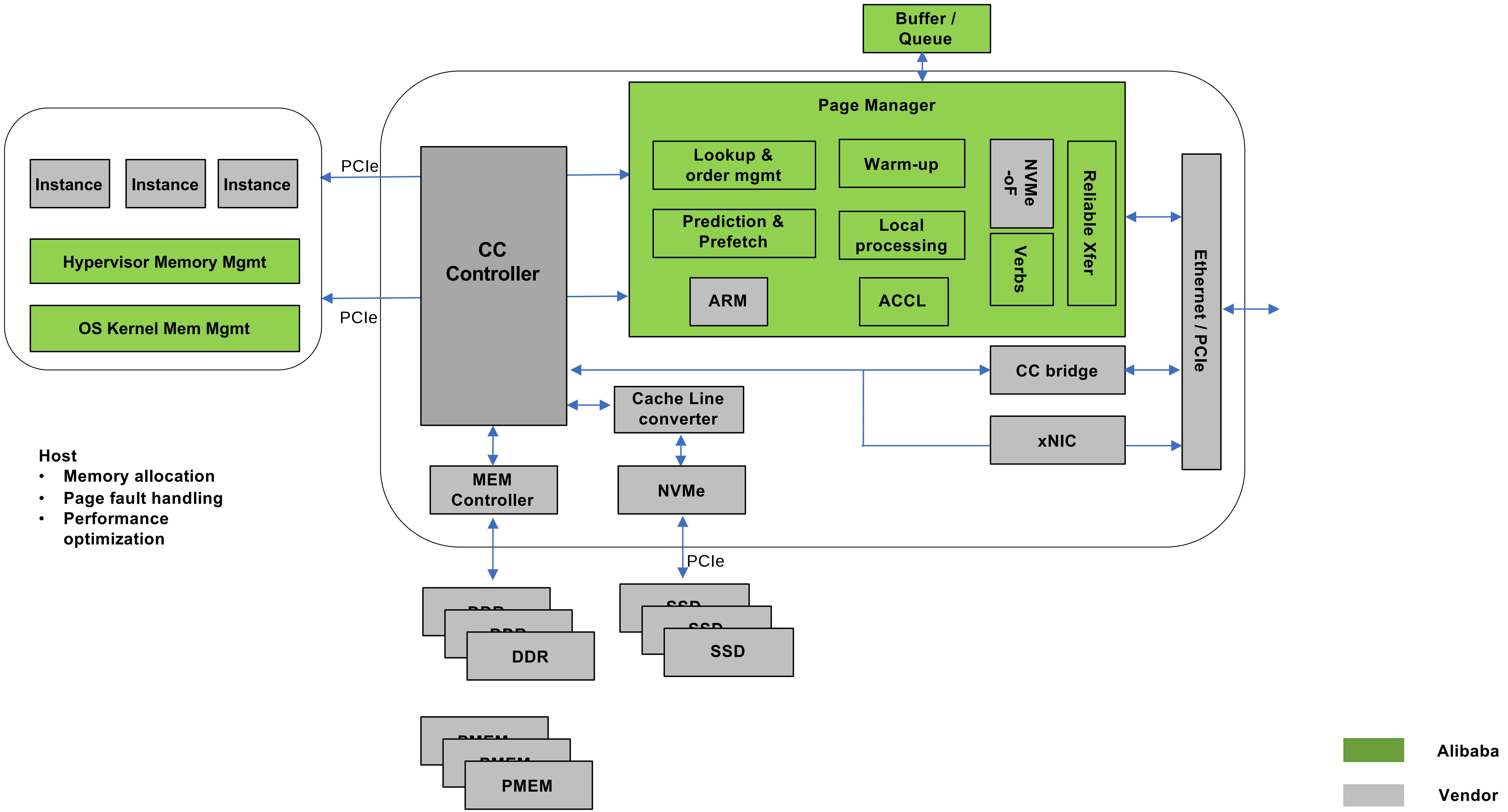


On Compute & Rack



Host

- **Memory allocation**
- **Page fault handling**
- **Performance optimization**

Workloads & Potential Benefits

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Type	Test	Potential Benefits
Traditional Compute	Mid to high utilization	Lower performance, higher density
Middleware	E-Commerce	Lower performance, higher density
Micro Services	E-Commerce	Lower performance, higher density
AI	Ali Native training & inference	Unacceptable for training
Encyption & Compression	Standard payload pre-/post-processing	Easier to scale out
Placement & Migration	Large instances	Faster; saving network b/w
Checkpointing & Mirroring	Cloud based HPC	High performance checkpointing enabled
NFV	Host gateway	Depends; easier to provision
Database	In-memory DB	Cost down significantly
Graph	Large social apps	Cost down significantly; minor programming model change
Upgrade & Deployment	Patching & initialization	Faster upgrade & composing

Power Management Platform

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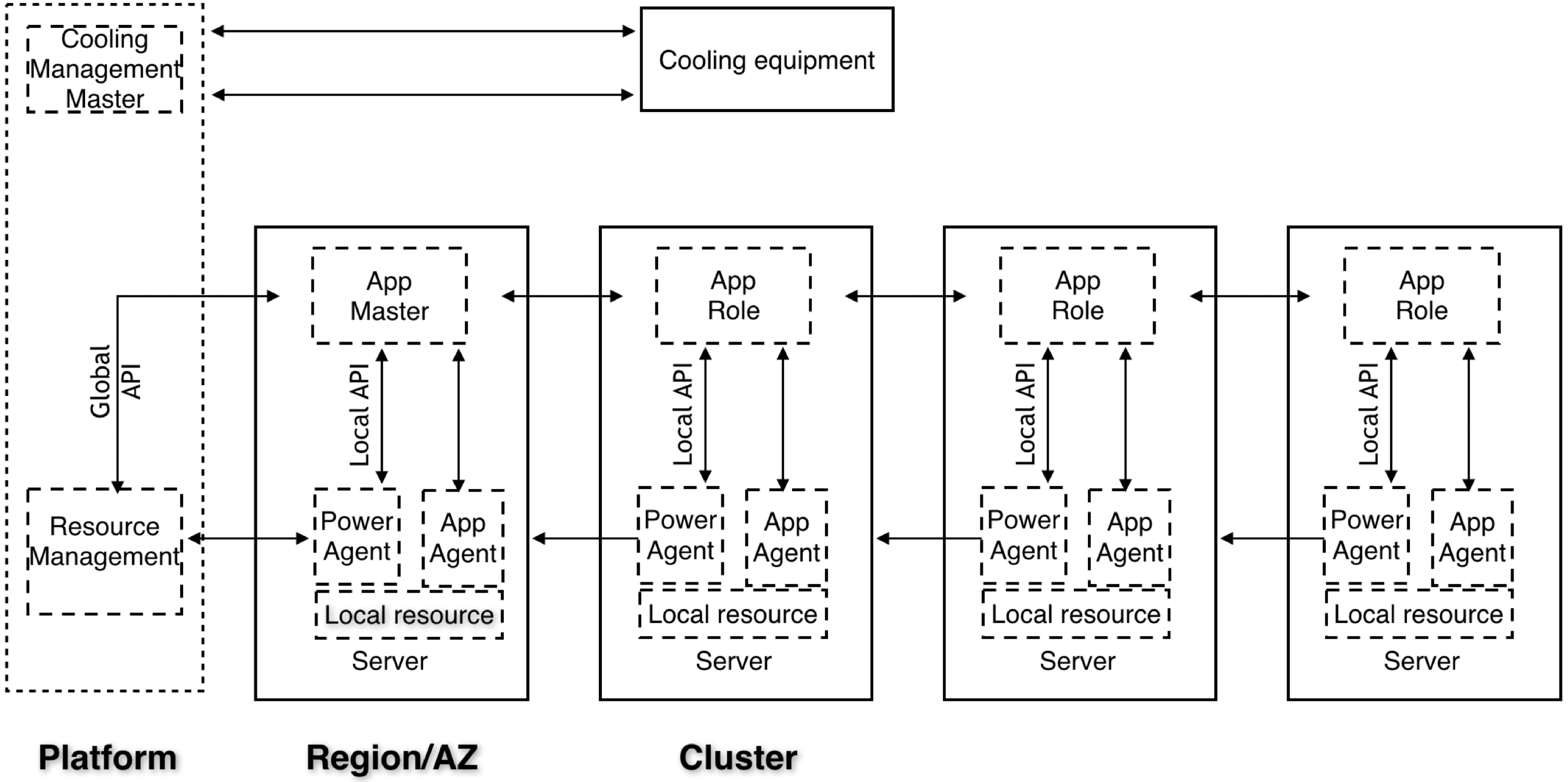
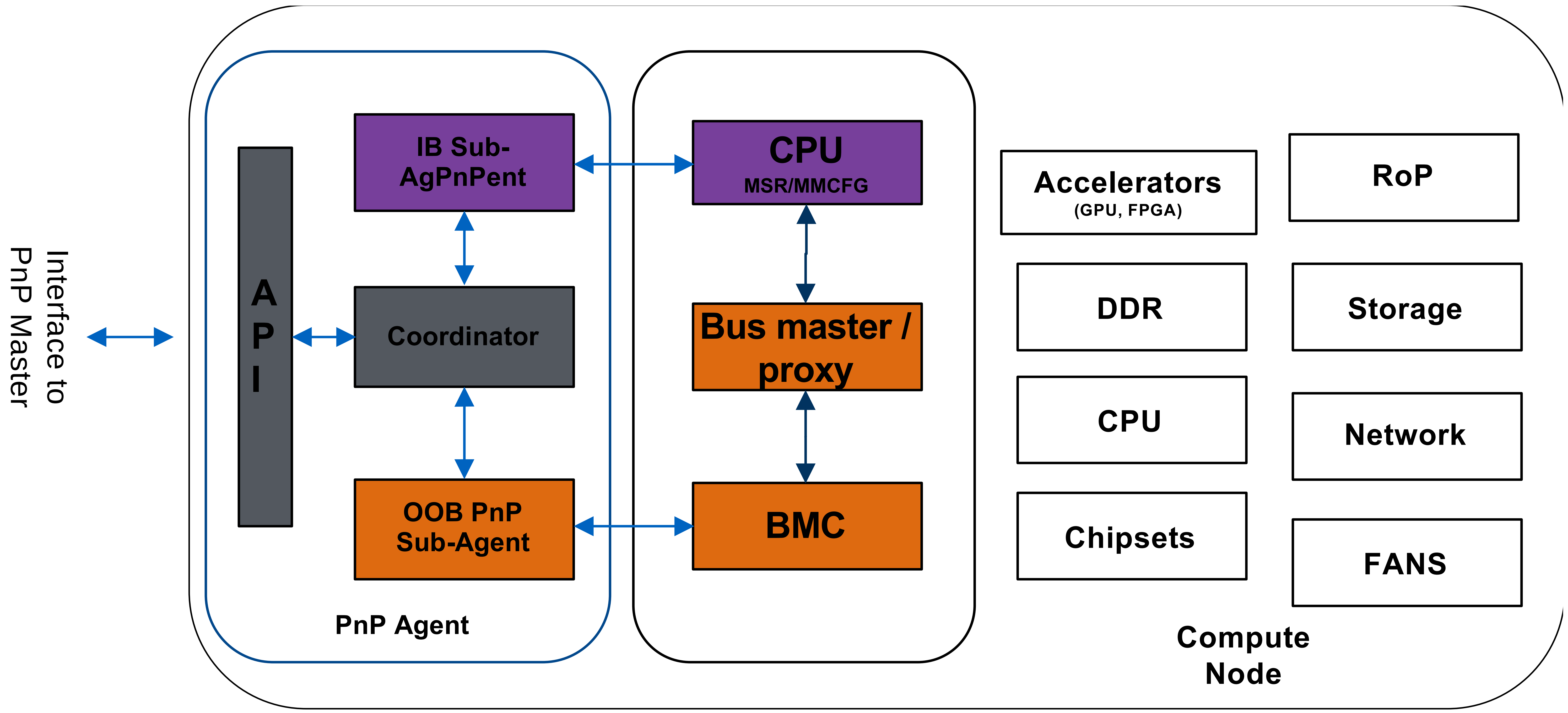


Highly Available Management



Alibaba Power Agent

- In-Band Power Management
- Out-of-Band Power Management

Server Platform

- Fine granularity power and performance telemetry & control knobs
- In-Band and Out-of-Band Control Channels

Capping & Budgeting

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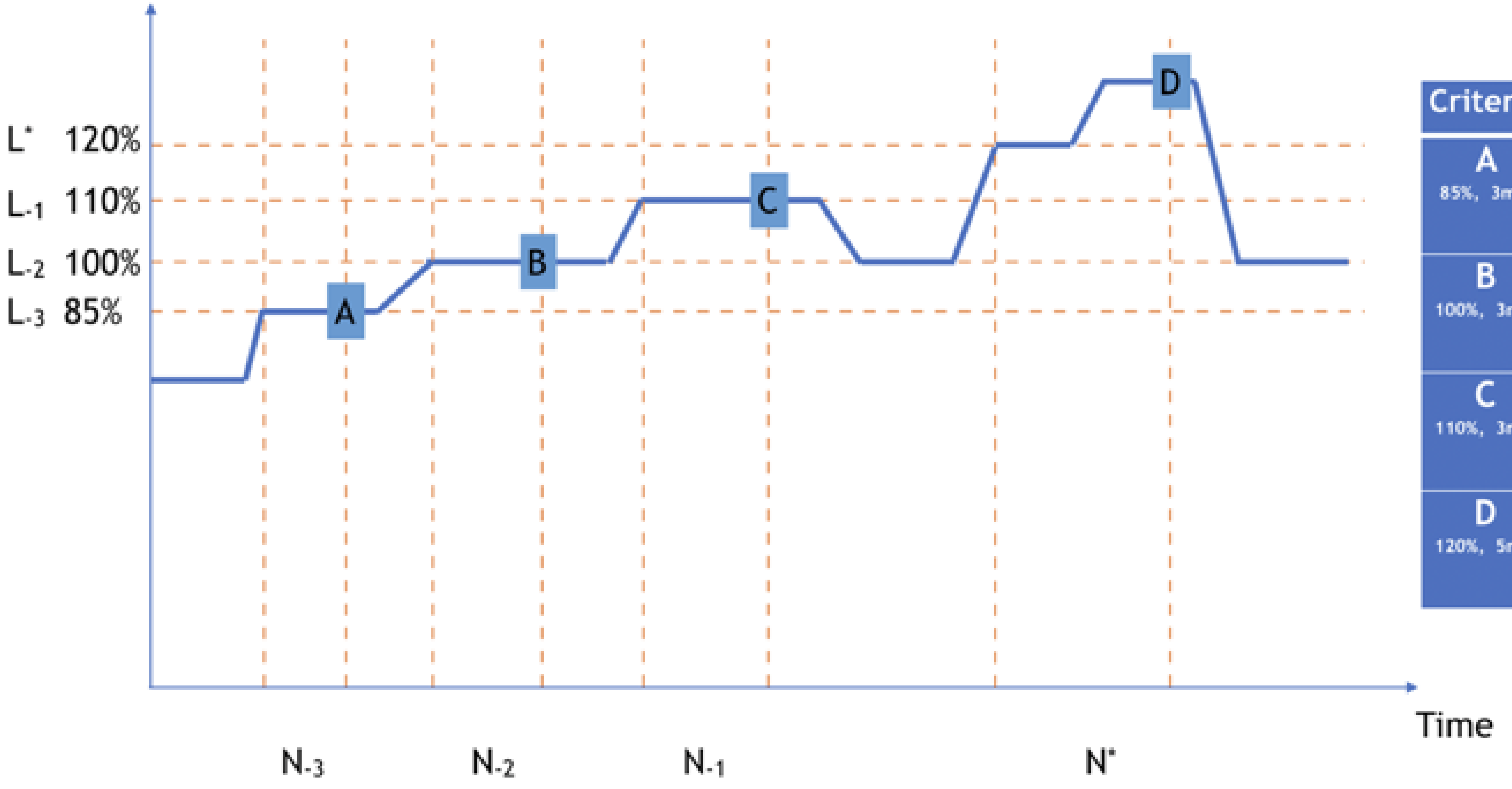
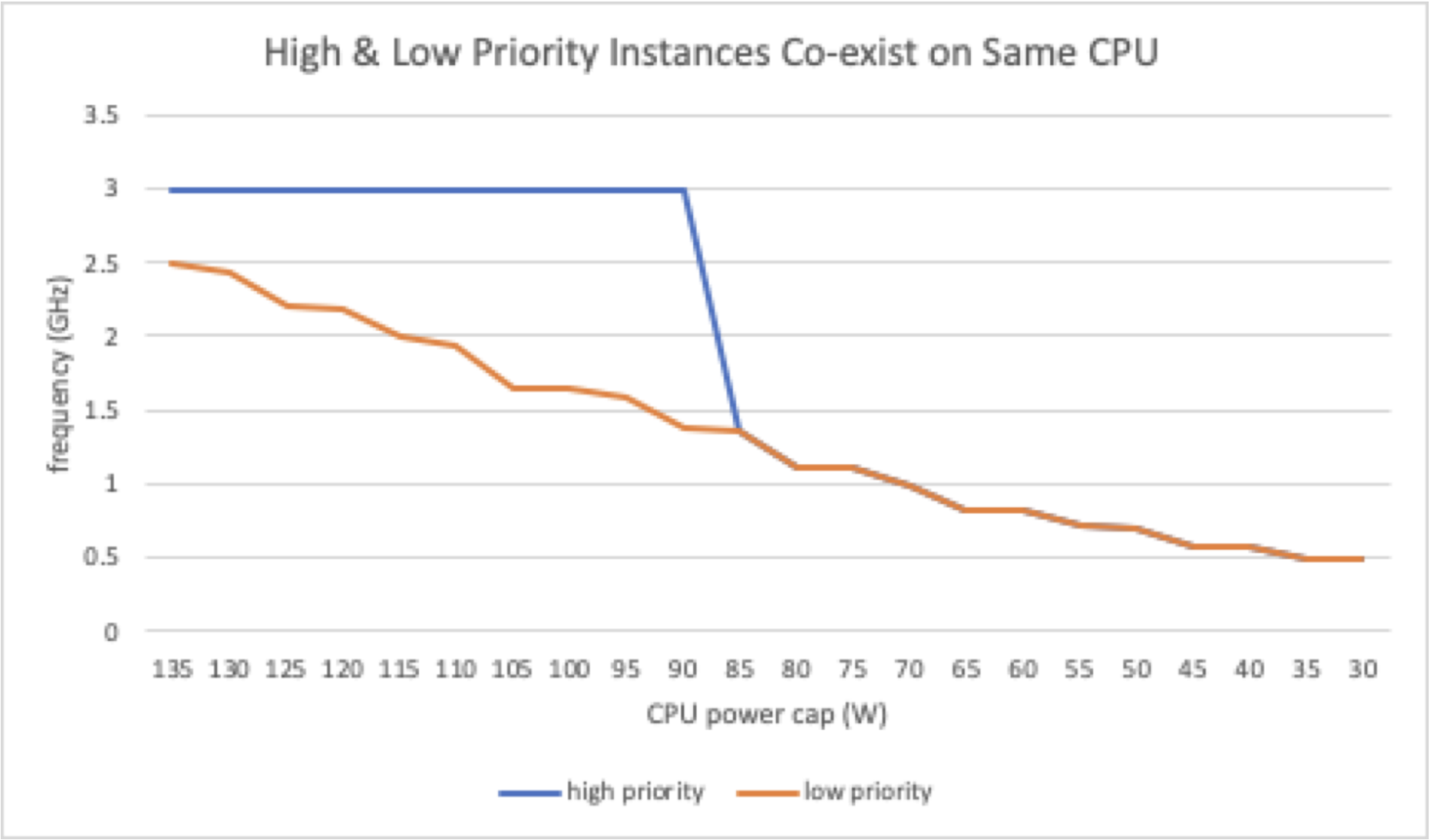


Criteria	Operation
A 85%, 3min	Rebalance
B 100%, 3min	Stop adding instances
C 110%, 3min	Super apps flow control
D 120%, 5min	Power capping with performance SLA

Rack/Node Power Capping



App Driven Power Budgeting

Performance Awareness

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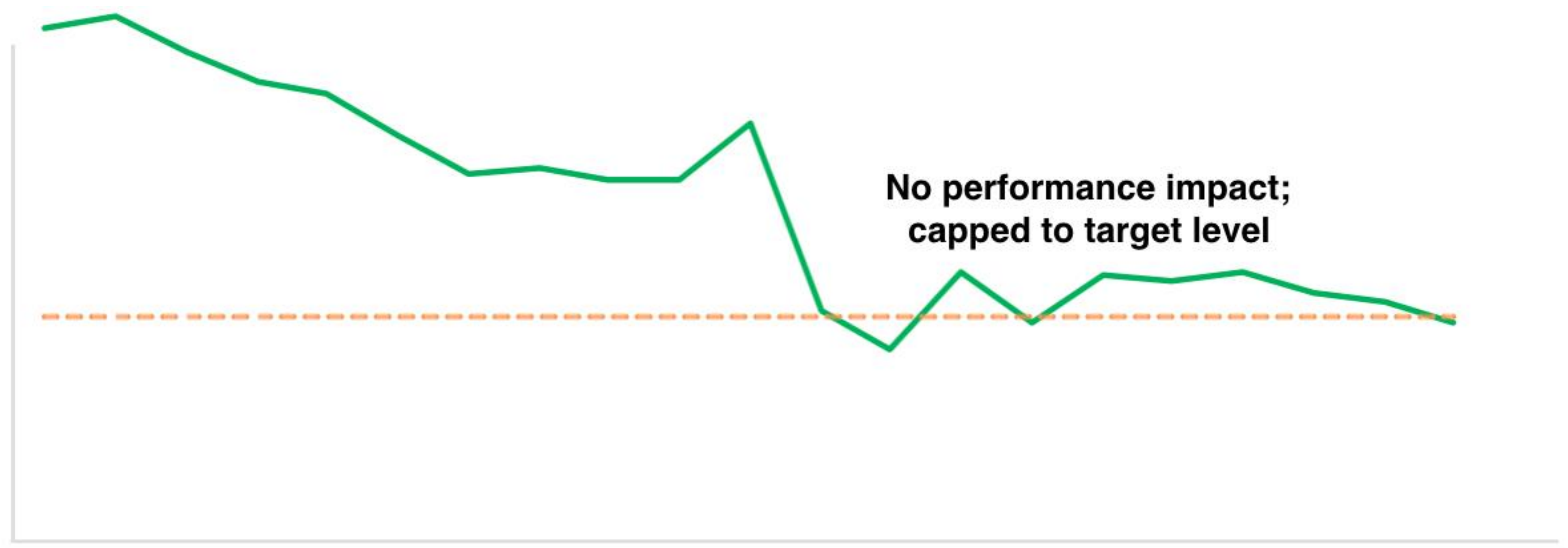
Type	Target	Note
Availability		Align w/ apps
Service delay	1s	Local
	30s	Global
Models coverage	Based on spec & test results	
Racks coverage	Based on spec & test results	
Power watermarks	Defined by apps & platform	
Capping accuracy	5%	
Priority	Defined by apps	Low priority nodes first capped
Fmin	Defined by apps Lifted by AI	Anytime higher than Fmin
Granularity	By core (CPU), rank (mem), link (IO) and device (storage)	
Capping - DVFS	Minimal performance impact	Defined by apps
Capping - CCx	**Minimal latency impact**	Defined by apps
In-Band	supported	
Out-of-Band	Partially supported	
Thermal watermarks	Defined by apps and platform	
Failover	Unconditional capping, autonomous capping, or S5	



Identify IDC, server and app control knobs with least performance impact

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