Pricing Games for Hybrid Object Stores in the Cloud: Provider vs. Tenant

Yue Cheng*, M. Safdar Iqbal*, Aayush Gupta†, Ali R. Butt*

*Virginia Tech & †IBM Research – Almaden

HotCloud’ 15
Cloud-based object stores

- Amazon S3
- Swift
- OpenStack
- Google Cloud Storage
Data analytics on object stores

Cloud tenants → Cloud object stores

Hadoop to object store connectors

Cloud object stores:
- Amazon S3
- OpenStack
- Google Cloud Storage

Tools and technologies:
- Hadoop
- Google Cloud Storage
- Swift
- OpenStack
- Amazon Web Services
- IBM
Data analytics on object stores

Amazon Web Service
Elastic MapReduce

Microsoft Azure
HDInsight
Cloud-based object stores

- Amazon S3
- swift
- openstack
- Google Cloud Storage
HDD-based object store?

HDD price: $0.0011/GB/day

Trace 1: 12TB input 5TB output
Trace 2: 18TB input 8TB output

Tenants cannot meet deadline
Provider get low profit
SSD-based object store helps meet workload deadline for tenants while increasing profit for provider.

HDD price: $0.0011/GB/day
SSD price: $0.0044/GB/day

Trace 1: 12TB input 5TB output
Trace 2: 18TB input 8TB output
SSD-based object store? Helps meet workload deadline for tenants while increasing profit for provider.

Pure SSD deployment may not be practical!

HDD price: $0.0011/GB/day
SSD price: $0.0044/GB/day

Trace 1: 12TB input 5TB output
Trace 2: 18TB input 8TB output

Normalized cloud profit vs. Tenant workload runtime (hour)
A hybrid object store?

Tenant workload runtime (hour)

SSD only, trace 2
HDD+SSD, trace 2
HDD+SSD, trace 1
HDD only, trace 1
HDD only, trace 2

Normalized cloud profit

Tenant: workloads meet deadline
Provider: comparatively high profit

HDD price: $0.0011/GB/day
SSD price: $0.0044/GB/day

Trace 1: 12TB input 5TB output
Trace 2: 18TB input 8TB output
More options in a hybrid setup

- HDDs (different RPMs)
- NAND flash SSDs (SATA, PCIe, etc.)
- SCMs (PCM, RRAM, etc.)
More options in a hybrid setup

- **HDDs**
  - different RPMs

- **NAND flash SSDs**
  - SATA, PCIe, etc.

- **SCMs**
  - PCM, RRAM, etc.

**Performance/endurance trade-off**
More options in a hybrid setup

- **HDD**
  - High read latency
  - Low cost per GB
- **SSD**
  - Low read latency
  - High cost per GB
- **SCMs** (PCM, RRAM, etc.)
  - Performance/endurance trade-off
A dynamic pricing model

- Two objectives
  - Objective 1: to balance the increasing profit and SSD wear-out rate
  - Objective 2: to provide incentivizing mechanism to tenants
A dynamic pricing model

- Dynamic pricing engages both provider and tenants in a pricing game
- Objectives of provider and tenants are essentially conflicting!
The leader/follower game

**Provider** leader

**Tenant** follower

- **Step 1:** Make price decision
  - Time slot $n$
  - SSD price $P_{(n,ssd)}$
  - Fraction of SSD used $f_{(n,ssd)}$
  - Writes on SSD $w_{(n,ssd)}$

- **Step 2:** Make tiering decision based on requirement
  - Time slot $n+1$
to maximize   \[ \text{Profit} = \sum_i \left( \sum_s \left( \text{Capacity}_{(i,s)} \cdot f_{(i,s)} \cdot p_{(i,s)} \right) - \text{Cost}_i \right) \]

SSD writes 

% SSD demand 

SSD price as decision variable

- SSD writes
- % SSD demand
- SSD price as decision variable
Tenant model

To maximize

\[ Utility = \frac{1}{T} \]

Simulated annealing

\[ J_0: <s_0, c_0> \]
\[ J_1: <s_1, c_1> \]
\[ J_2: <s_2, c_2> \]

... Assigned job storage, adjusted storage capacity

* CAST [HPDC’15]
Provider-tenant interaction

A trace snippet (250-jobs) from production trace collected from a 3000-machine Hadoop deployment at Facebook: The same single-day trace replayed everyday
Provider-tenant interaction

A trace snippet (250-jobs) from production trace collected from a 3000-machine Hadoop deployment at Facebook:

*The same single-day trace replayed everyday*
Impact of different SSD pricing

Normalized cloud profit

<table>
<thead>
<tr>
<th>Static Low</th>
<th>Static Medium</th>
<th>Static High</th>
<th>Dynamic</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>2.5</td>
<td>1.0</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Normalized tenant utility

<table>
<thead>
<tr>
<th>Static Low</th>
<th>Static Medium</th>
<th>Static High</th>
<th>Dynamic</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>1.4</td>
<td>0.8</td>
<td>1.6</td>
</tr>
</tbody>
</table>

*static low: $0.0035/GB/day*
*static medium: $0.0082/GB/day*
*static high: $0.0121/GB/day*
Dynamic pricing + object storage tiering = cloud profit ↑ + tenant utility ↑