Problem statement

- Cloud services enable latency-sensitive applications to serve their applications from geographically distributed set of data centers
- However, isolated storage service is offered in every data center, leaving replication to applications
- Simple replication strategies (e.g., replicate to all data centers or maintain single replica) incur high cost

Use multiple cloud providers to minimize cost

<table>
<thead>
<tr>
<th>Cloud Provider</th>
<th>Latency Bound (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC2</td>
<td>25</td>
</tr>
<tr>
<td>GCS</td>
<td>50</td>
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<tr>
<td>Azure</td>
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</tr>
<tr>
<td>AWS</td>
<td>100</td>
</tr>
<tr>
<td>Datacenter 1</td>
<td>125</td>
</tr>
<tr>
<td>Datacenter 2</td>
<td>150</td>
</tr>
<tr>
<td>Datacenter 3</td>
<td>200</td>
</tr>
</tbody>
</table>

Key techniques

- Integer program run by placement manager to determine replication policy for every access set
- Workload considered per access set since aggregate workloads are more stable
- Asymmetric quorum sets to minimize cost and meet lower latency SLOs
- Novel two-phase commit protocol

Consistency and latency dependent replication

- Replicate everywhere: + Low GET latencies - High networking cost
- Store few copies: + Low storage cost - High GET/PUT latencies

Relay data propagation to reduce costs

- Use multicast trees to exploit bandwidth pricing discrepancies across regions.

Asymmetric quorum sets

- Lower latency SLOs can be met and reduces cost

Two-phase commit protocol

- Reduces costs for compute resources by sending data directly from application VMs to storage services. SPANStore’s VMs only involved in metadata operations.

SPANStore vs. single cloud

- SPANStore can lower cost by over 10x.

SPANStore vs. fixed policies

- SPANStore intelligently exploits price discrepancies and several other factors, which fixed policies cannot.

Using SPANStore in applications

- SPANStore meets specified latency SLOs for example social networking and collaborative document editing web services.