Performance of Containerized Database Management Systems

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Agenda

OS containers and databases

Comparing container configurations

Container resources

Operations

Evaluation
Containers are the new VMs

Virtualization at OS-kernel level instead of hardware level

- More lightweight because of higher abstraction level
- Software deployed as container image, which includes the userland OS
  - Several layers, the top layer is mutable but volatile
  - Persistent storage must be mapped into the container
- Largely independent of hardware → kernel API and resource assignments are relevant
  - Partitioning or virtualization, to collocate containers
  - Isolation of collocated containers is possible but hard to achieve
- Container orchestration (application execution e.g. by Kubernetes)
  → cross-OS compatibility
Comparing container configurations

Container-based deployment of software in the cloud

IaaS and container orchestration have various configuration options
- E.g. CPU allocation, storage class and QoS, network

How to compare these options?

Contribution
- Testing methodology to compare performance of different configurations under a wide range of workload
- Exemplified with Docker container engine and SAP HANA DB
Container resources

CPU
- Two options to assign hardware threads, dynamically changable
  - By total number (cpus)
  - By selection of threads (cpusets)

Volatile memory
- Overprovisioning not allowed to avoid OoM hazard
- Should take NUMA into account

Persistency
- Persistent filesystem must be mapped from outside

Network
Operations: persistency striping for log volume

Shared volumes
- Parallel accesses allow for increased performance
- Low fragmentation

Dedicated volumes
- Physical separation of data
- Lower performance with reduced number of stripes
- Higher storage consumption and fragmentation
Operations: CPU elasticity

**cpus**: shared sockets

- Easy to overprovision
- No control over NUMA placement

**cpusets**: pinned sockets

- Partitioning, no simple overprovisioning
- Supports NUMA-aware database
Operations: container migration

Hardware issues, maintenance, changing resource demand → container to move to different host

VMs usually support live migration, but container live-migration is not generally supported

Database can be transferred with near-zero downtime using system replication

- Steps: add secondary, replicate data, takeover, remove secondary (former primary)

If system replication is too expensive, external persistency needs to be switched

Depending on storage configuration

- Dedicated volumes can be re-mounted on target host
- Shared volumes need to be copied
Performance testing methodology

Aim
- Simple comparison of container configuration options
- Based on diverse workload
- In isolation as well as in presence of noisy neighbors

Test suite
- Approx. 700 measurement points reporting either CPU time, elapsed time or cycle time
- OLTP: 5 queries on 1 or two tables with 100 clients
- OLAP: 4 queries on up to 38 tables
- 95% of measurement points have a coefficient of variation less than 5%

How to get an overview of the comparison of 700 measurement points μ?

\[
\begin{align*}
\text{min}(\mu) & := \min(\text{avg}(\mu, A), \text{avg}(\mu, B)) \\
\text{delta}(\mu) & := \text{avg}(\mu, B) - \text{avg}(\mu, A) \\
\text{regression}(\mu) & := 100 \times \frac{\text{delta}(\mu)}{\text{min}(\mu)}
\end{align*}
\]

Procedure
- Create bins of regression values
- Display the bins as histogram, together with mean and percentiles
- Skew shows if and how much the configurations differ

Aim
- Simple comparison of container configuration options
- Based on diverse workload
- In isolation as well as in presence of noisy neighbors
Evaluation: baremetal baseline and VMs with noisy neighbor

**baremetal**

![Graph showing regression statistics and outliers for baremetal baseline and VMs without/with noisy neighbor.]

- **Baremetal A**
  - Regression statistics:
    - 10th perc.: 430
    - Avg.: 135
    - 90th perc.: 17
  - Outliers: min = -16, max = 7

- **Baremetal B**
  - Regression statistics:
    - 10th perc.: 104
    - Avg.: 0
    - 90th perc.: 1

**VMs without/with noisy neighbor**

- **Single VM**
  - Regression statistics:
    - 10th perc.: 256
    - Avg.: 190
    - 90th perc.: 50
  - Outliers: min = -4, max = 18

- **VM with NN**
  - Regression statistics:
    - 10th perc.: 103
    - Avg.: 56
    - 90th perc.: 12
Evaluation: CPU assignment (impact of noisy neighbor)

- **cpuset (pinned CPUs)**
  - **Regression statistics**
    - 10th perc.: 10th percentile
    - avg.: average
    - 90th perc.: 90th percentile
  - **Outliers**
    - min = -52
    - max = 104
  - Frequency distribution for regression bins

- **cpus (shared sockets)**
  - **Regression statistics**
    - 10th perc.: 10th percentile
    - avg.: average
    - 90th perc.: 90th percentile
  - **Outliers**
    - min = -56
    - max = 210
  - Frequency distribution for regression bins
Evaluation: CPU assignment (cpuset vs. cpus)

- **without noisy neighbor**
  - cpuset - no NN
  - cpus - no NN

- **with noisy neighbor**
  - cpuset with NN
  - cpus with NN
Evaluation: storage striping (dedicated storage vs. shared storage)
Thank you.

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