

Priority-driven Differentiated Performance for NoSQL Database-as-a-Service

Remo Andreoli, Tommaso Cucinotta, and Daniel Bristot De Oliveira

Abstract—Designing data stores for native Cloud Computing services brings a number of challenges, especially if the Cloud Provider wants to offer database services capable of controlling the response time for specific customers. These requests may come from heterogeneous data-driven applications with conflicting responsiveness requirements. For instance, a batch processing workload does not require the same level of responsiveness as a time-sensitive one. Their coexistence may interfere with the responsiveness of the time-sensitive workload, such as online video gaming, virtual reality, and cloud-based machine learning. This paper presents a modification to the popular MongoDB NoSQL database to enable differentiated per-user/request performance on a priority basis by leveraging CPU scheduling and synchronization mechanisms available within the Operating System. This is achieved with minimally invasive changes to the source code and without affecting the performance and behavior of the database when the new feature is not in use. The proposed extension has been integrated with the access-control model of MongoDB for secure and controlled access to the new capability. Extensive experimentation with realistic workloads demonstrates how the proposed solution is able to reduce the response times for high-priority users/requests, with respect to lower-priority ones, in scenarios with mixed-priority clients accessing the data store.

Index Terms—Cloud Computing, Differentiated Performance, NoSQL, Cloud Storage, MongoDB.

1 INTRODUCTION

OVER the past decade, Cloud Computing proved to be a cost-effective paradigm for businesses looking for ways to ease the development, deployment, monitoring, and operations of monolithic or distributed applications featuring continuous availability and reliability. In this regard, the Infrastructure-as-a-Service (IaaS), Software-as-a-Service (SaaS), and Platform-as-a-Service (PaaS) cloud paradigms allow customers to avail of a number of services with on-demand capabilities, avoiding the capital investment and maintenance burden of on-premise infrastructures [1]. One of the key advantages of the cloud computing paradigm is the decoupling between *providers*, who manage the physical infrastructure and offer cloud services fully managed on a 24/7 basis, and *customers* (or *tenants*), who use them. Cloud-native software [2] makes use of many techniques to efficiently operate at a global scale on multiple geo-distributed, fault-independent sites, such as data replication and sharding, horizontal scalability, load balancing, and efficient orchestration of virtual machines and containers.

At the heart of the cloud-native distributed software ecosystem, there are storage services, which must address the stringent performance, reliability, and scalability requirements of today's database-driven web applications. These often perform massive big-data processing, as in extreme-scale simulations [3] or application scenarios making use of machine learning and artificial intelligence. This has led to a new generation of data stores, named NoSQL, to

highlight the difference compared to the relational counterpart, which employs more relaxed design choices, departing from traditional ACID guarantees to embrace schema-less and weak-consistency data models and simpler APIs, gaining in efficiency and scalability.

Since the success of a cloud-based application is directly correlated to the quality of the user experience, the so-called Quality-of-Service (QoS), it is fundamental for a cloud provider (CP) to consistently provide performance levels as expected by its customers, whether implicit or formally defined in an in-place Service Level Agreement (SLA). A well-known [4], [5], [6] performance-related challenge in Cloud Computing is to provide predictable response times for time-sensitive, low-latency, and interactive applications, such as video streaming, online gaming [7], social networks in virtual and augmented reality [8] and Internet-of-Things (IoT) network systems, which all intrinsically possess tight responsiveness requirements.

In this context, a CP should expose managed virtualized infrastructure elements (e.g., virtual machines) and cloud services (e.g., storage solutions) that exhibit stable and predictable performance to build reliable applications that satisfy the timing constraints necessary for high-quality interactivity with minimum degradation [4], [9]. However, multi-tenant architectures are well-known to suffer from the “noisy neighbor” effect. This can be tackled by deploying dedicated hardware, but it is quite expensive, whilst normally CPs save on operational costs and energy consumption by applying resource consolidation techniques [10], [11], [12] to maximize the infrastructure utilization and help running a sustainable and cost-effective service. For instance, multiple VMs can be hosted on the same physical machine, or data from multiple independent tenants may be stored within a single scalable data store, to reduce

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