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Cover Letter for Discussion Leader
CSE-60876 (Research Methods)

- **Paper Title** FIRM: An Intelligent Fine-grained Resource Management Framework for SLO-Oriented Microservices
- **General Topic** Th FIRM framework focuses on improving the performance of fine-grained resource management for SLO-oriented microservices using machine learning techniques.
- **Specific Behavior or Activity Studied** FIRM addresses the challenge of predictably sharing compute resources across microservices to improve overall utilization without violating Service Level Objectives (SLOs) due to resource contention.
- **Research Questions**
  - How can resource contention causing SLO violations in microservices be detected and localized?
  - What methods can dynamically mitigate these SLO violations through resource reprovisioning?
  - How can machine learning models be utilized to predict and manage shared resources among microservices more efficiently?
- **Challenges**
  - Identifying how shared resource contention affects microservices' performance and SLO compliance.
  - Creating a system that dynamically adjusts resources to prevent SLO violations in real-time.
- **Paradigm** FIRM employs a multilevel machine learning-based resource management framework, focusing on fine-grained control of shared resources to enhance performance isolation and resource utilization.
- **Problem** The problem highlighted in this paper centers on the difficulties of shared resource management in microservices architectures, particularly how to prevent SLO violations in a landscape characterized by its dynamic and distributed nature. Traditional strategies have struggled, mainly relying on over-provisioning or static resource allocation models that lack the flexibility to efficiently adapt to changing workloads and demands for resources. This inefficiency often leads to unnecessary SLO violations, impacting service reliability and user satisfaction.
- **Importance**
  - Effective resource management is essential for meeting SLOs, ensuring user satisfaction, and protecting service providers from financial and reputational harm.
  - Optimizing resource allocation reduces excessive provisioning, resulting in cost-effective operations and sustainable IT infrastructures through intelligent resource usage.
- **Claims**
  - FRIM reduces overall SLO violations by up to 16× compared with Kubernetes autoscaling, and 9× compared with the AIMD-based method, while reducing the overall requested CPU by as much as 62
  - FIRM outperforms the AIMD-based method by up to 9× and Kubernetes autoscaling by up to 30× in terms of the time to mitigate SLO violations.
  - FIRM improves overall performance predictability by reducing the average tail latencies up to 11×.
  - FIRM successfully localizes SLO violation root-cause microservice instances with 93% accuracy on average.

- **State of Knowledge** Prior to FIRM, research on microservices resource management relied on static models and over-provisioning, which lacked efficiency and adaptability to changing demands. There was a notable gap in dynamically and finely managing shared resources to prevent SLO violations
- **Theoretical and/or Empirical Evidence** Through extensive testing across four microservice benchmarks, FIRM proves its efficacy by significantly reducing SLO violations and optimizing CPU resource requests, demonstrating marked improvements in resource utilization and service performance.
- **Story Structure** In this paper, the authors first pinpoint the challenge of managing shared resources and avoiding SLO violations in microservices. To tackle this, the introduce FIRM, a framework that uses a two-phase machine learning approach for dynamic resource control. Initially, an SVM model detects and localizes SLO violations, then a Reinforcement Learning (RL) model adapts resource allocation to mitigate these issues. Extensive testing on real-world benchmarks validates FIRM's ability to significantly reduce SLO violations and improve resource efficiency, highlighting the effectiveness of integrating SVM and RL for resource management.