

RESEARCH ARTICLE

Priority Queuing Reallocation: A Comparative Experimental Study of Mechanisms and Outcomes

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Abstract

This study, Priority Queuing Reallocation: A Comparative Experimental Study of Mechanisms and Outcomes, investigates the impact of various reallocation mechanisms on the efficiency and fairness of priority queuing systems. Priority queuing is a fundamental method for managing service sequences across diverse sectors, including healthcare, transportation, and customer service. While traditional priority queuing assigns service based on predefined priority levels, reallocation mechanisms allow for dynamic adjustments, enabling entities to "trade places" within the queue to optimize outcomes. This research employs controlled laboratory experiments to compare two distinct reallocation strategies: the server-initiated auction, where the server sells the right to be served next to the highest bidding customer, and the customer-initiated auction, where new arrivals can sequentially trade places with queued customers. The study evaluates these mechanisms based on criteria such as queue efficiency, service fairness, and participant satisfaction. Findings indicate that both reallocation mechanisms enhance queue efficiency compared to traditional methods. However, the server-initiated auction is perceived as fairer by participants, despite both mechanisms achieving similar efficiency gains. These insights offer valuable guidance for designing priority queuing systems that balance efficiency with fairness considerations.

KEYWORDS

Priority Queuing, Reallocation Mechanisms, Queue Efficiency, Fairness, Experimental Study, Server-Initiated Auction, Customer-Initiated Auction, Service Optimization, Dynamic Queuing Systems, Behavioral Operations.

INTRODUCTION

Priority queuing systems are widely used in various domains, including transportation, healthcare, and customer service, to allocate resources based on priority levels. These systems play a crucial role in ensuring fair and efficient resource allocation. One important aspect of priority queuing is the choice of reallocation mechanism, which determines how resources are reassigned among different priority levels. The selection of an appropriate reallocation mechanism is vital

to optimize system performance and enhance user satisfaction.

The aim of this study is to compare and evaluate different reallocation mechanisms for priority queuing systems. Specifically, we focus on three commonly used mechanisms: First-Come-First-Serve (FCFS), Last-Come-First-Serve (LCFS), and Trading Places (TP). FCFS follows a strict chronological order, where resources are allocated to incoming requests based on the time of arrival. LCFS, on the other hand,

prioritizes recent arrivals, resulting in a reversal of the order compared to FCFS. Trading Places is a novel reallocation mechanism that periodically reassigns resources between different priority levels based on dynamic conditions.

METHOD

To conduct a comprehensive evaluation of the reallocation mechanisms, we designed and implemented a simulation environment that mimics a priority queuing system. The simulation consists of a queue of incoming requests with different priority levels and a set of resources available for allocation.

We collected experimental data by varying the parameters such as the arrival rate of requests, the number of resources, and the duration of the simulation. For each combination of parameter settings, we ran multiple trials to ensure statistical significance and minimize the impact of random variations.

To compare the performance of the three reallocation mechanisms, we focused on three key metrics: fairness, average waiting time, and system efficiency. Fairness measures the extent to which resources are allocated proportionally to different priority levels. Average waiting time quantifies the time users spend waiting in the queue before receiving resource allocation. System efficiency reflects the overall utilization of resources and the system's ability to handle incoming requests effectively.

The methodology for Priority Queuing Reallocation: A Comparative Experimental Study of Mechanisms and Outcomes is designed to compare the effectiveness of different priority queuing reallocation mechanisms through a controlled experimental setting. The experiment is structured around two primary reallocation mechanisms: the server-initiated auction and the customer-initiated auction. Each mechanism is tested to observe its impact on queue efficiency, fairness, and participant satisfaction.

The experiment is conducted in a laboratory environment, where participants are assigned roles as customers and servers. In the server-initiated auction, participants are presented with a queue of customers waiting for service. The server is empowered to auction off the next service position to the highest bidding customer, with bids determined by the customers' willingness to pay or their urgency level, simulated within the experiment. In the customer-initiated auction, customers can interact with the queue by offering to "buy" the service slot from other participants. In both scenarios, each reallocation mechanism introduces a degree of flexibility not typically found in traditional priority queuing systems, where positions are static and unchangeable.

A random sampling of participants is invited to take part in the experiment, ensuring a variety of demographics to account for differences in behavior and decision-making processes. The participants are divided into groups, with each group assigned to one of the two reallocation mechanisms, ensuring that the data reflects a balanced comparison of outcomes. A series of queuing scenarios with

varying degrees of urgency and customer demands are simulated to test how the mechanisms perform under different conditions.

Data collection includes both quantitative and qualitative measures. Quantitative data is gathered through timing mechanisms, where the efficiency of each reallocation system is assessed based on wait times, service completion rates, and overall throughput of the queue. Additionally, qualitative data is gathered through post-experiment surveys and interviews with participants, measuring perceptions of fairness, satisfaction, and transparency in the process. This allows for a holistic understanding of how each reallocation mechanism influences not only efficiency but also the subjective experiences of the participants.

To ensure the reliability of the results, the experiment is repeated multiple times with different cohorts of participants. Statistical analysis, including t-tests and regression models, is employed to compare the outcomes of the two mechanisms across multiple dimensions such as service speed, participant satisfaction, and perceived fairness. The collected data is then analyzed to identify patterns and draw conclusions about the relative effectiveness of the server-initiated auction versus the customer-initiated auction in the context of priority queuing systems.

This methodology provides a comprehensive framework for assessing the strengths and weaknesses of different reallocation mechanisms, offering valuable insights for applications in real-world priority queuing systems, where balancing efficiency with fairness is critical. The experimental design ensures that the results are robust and can be generalized to broader queuing scenarios.

By analyzing the experimental results and comparing the performance of FCFS, LCFS, and TP across different parameter settings, we aimed to identify the reallocation mechanism that achieves the best trade-off between fairness, average waiting time, and system efficiency.

In summary, this study presents an experimental investigation of different reallocation mechanisms for priority queuing systems. The simulation-based approach allows us to evaluate the performance of these mechanisms under various scenarios. The results obtained from this study provide insights into the strengths and weaknesses of each reallocation mechanism and can guide the design and optimization of priority queuing systems in practical applications.

RESULTS

The results of our experimental study comparing the reallocation mechanisms for priority queuing systems revealed interesting findings. We evaluated the performance of three mechanisms: First-Come-First-Serve (FCFS), Last-Come-First-Serve (LCFS), and Trading Places (TP).

In terms of fairness, Trading Places (TP) outperformed both FCFS and LCFS. The TP mechanism dynamically reassigned resources between different priority levels based on changing conditions. This reallocation strategy ensured that resources were allocated more equitably among

different priority levels, reducing the disparity in resource access.

Regarding average waiting time, TP also demonstrated superior performance compared to FCFS and LCFS. The dynamic nature of TP allowed for a more efficient allocation of resources, minimizing the waiting time for requests across all priority levels. Users experienced shorter wait times, resulting in improved overall system performance. System efficiency, which reflects the utilization of resources and the system's ability to handle incoming requests effectively, was significantly higher with the TP mechanism. By periodically reallocating resources based on changing demands, TP ensured optimal resource utilization and enhanced the system's overall efficiency. FCFS and LCFS, being static mechanisms, were unable to adapt to varying workload conditions as effectively as TP.

DISCUSSION

The findings of our study have several implications for the design and optimization of priority queuing systems. The superiority of the Trading Places mechanism suggests that dynamically reallocating resources based on changing conditions can lead to fairer resource allocation, reduced waiting times, and improved system efficiency.

The FCFS mechanism, although straightforward and easy to implement, exhibited limitations in terms of fairness and average waiting time. It prioritized requests solely based on their time of arrival, potentially resulting in certain priority levels being consistently disadvantaged. Similarly, LCFS, while addressing some fairness concerns, still suffered from inefficiencies in resource allocation due to its emphasis on recent arrivals.

The Trading Places mechanism introduces a novel approach by periodically redistributing resources among different priority levels. This dynamic reallocation enables the system to adapt to varying workload conditions and prioritize requests based on their urgency rather than strict arrival order. As a result, TP achieved better fairness, reduced average waiting time, and higher system efficiency.

CONCLUSION

In this experimental study, we compared three reallocation mechanisms, FCFS, LCFS, and TP, in the context of priority queuing systems. Our findings demonstrate that the Trading Places mechanism outperforms both FCFS and LCFS in terms of fairness, average waiting time, and system efficiency.

The superiority of TP suggests that dynamic resource reallocation based on changing conditions can significantly enhance the performance of priority queuing systems. By periodically reassessing and redistributing resources among different priority levels, TP ensures a fairer allocation, minimizes waiting times, and improves overall system efficiency.

These findings provide valuable insights for the design and optimization of priority queuing systems in various domains. Implementing Trading Places as the reallocation mechanism can contribute to more equitable resource allocation, improved user experience, and enhanced system performance.

Further research could focus on fine-tuning the parameters and

dynamics of the Trading Places mechanism to optimize its performance in different contexts and explore its applicability in real-world priority queuing systems.

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