Data-Driven Queueing Models for Healthcare: Accounting for Stochastic Dependence and Time Dependence (1634133)

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Abstract

Some emergency department (ED) patients experience long delays in being transferred from the ED to a bed within the main hospital, a phenomenon called ED boarding. While ED boarding can be caused by surges of demand in the ED, it also can be caused by operating policies in the hospital wards where the patient needs a bed. To properly understand ED boarding, it is necessary to take a broader view, looking at the rest of the hospital in addition to the ED itself. The problem of ED boarding and other patient flows in hospitals can be modeled as multi-class networks of queues. Accordingly, this research will develop new ways to analyze complex data-driven queueing network models in healthcare. This research will draw on the extensive experience with queueing network models to reduce congestion and improve the efficiency of manufacturing, computer and communication systems. The queueing network models needed in healthcare are more complicated because they require (i) classifying patients and resources, with priorities, and (ii) accounting for time-varying arrival rates and complicated stochastic dependence in the patient flows. Healthcare presents a new opportunity for fruitful applications of these queueing network models because the models can be fit to healthcare patient flow data, which are rapidly becoming available. In undertaking this research, the PI remains committed to helping to develop new researchers from traditionally under-represented groups.

This project will develop new tractable data-driven analytical approximations and simulation methods for time-varying multi-class queueing network models. New approximation methods will combine the recently developed robust optimization with established approximations for stochastic processes based on heavy-traffic limits and partial characterizations of stochastic dependence, such as indices of dispersion. A new robust queueing (RQ) formulation is proposed for exposing the performance impact of the time dependence and stochastic dependence in the flows. The new RQ formulation is based on the cumulative rate and variance of each flow for each class, represented as the total input of work as functions of time. The research will investigate if the new RQ optimization is effective and tractable; i.e., if it can indeed expose the impact of the time dependence and stochastic dependence on the performance of the queue. The impact of priorities also will be studied. Computer simulation will be used to evaluate the approximations and also directly as a performance analysis tool. This research will investigate new simulation methods for these time-varying models, including a new rare-event simulation method for the time-varying single-server queue. The methods will be tested by experiments with simulation and system data.