Stochastic modeling and optimization of garbage collection algorithms in solid-state drive systems.

Summary: Markov chains and mean-field analysis are powerful tools and widely used for performance analysis in large-scale computer and communication systems. In this paper, we consider the application of Markov modeling and mean-field analysis to solid-state drives (SSDs). SSDs are now widely deployed in mobiles, desktops, and data centers due to their high I/O performance and low energy consumption. In particular, we focus on characterizing the performance-durability tradeoff of garbage collection (GC) algorithms in SSDs. Specifically, we first develop a stochastic Markov chain model to capture the I/O dynamics of large-scale SSDs, then adapt mean-field analysis to derive the asymptotic steady state, based on which we are able to easily analyze the performance-durability tradeoff of a large family of GC algorithms. We further prove the model convergence and generalize the model for all types of workload. Inspired by this model, we also propose a randomized greedy algorithm (RGA) which has a single tunable parameter to trade between performance and durability. Using trace-driven simulation on DiskSim with SSD add-ons, we demonstrate how RGA can be parameterized to realize the performance-durability tradeoff.

Keywords: solid-state drives; garbage collection; wear-leveling; cleaning cost; Markov model; mean-field analysis

doi:10.1007/s1134-014-9405-y