Mathematical modeling of transport systems through exclusion process with finite resources.

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Multi-lane transport networks, found in both biological and vehicular systems, pose a considerable challenge in understanding particle movement, particularly in biological contexts**.** Nearly every system operates with limited resources. The tendency of particles to switch lanes under favorable conditions further complicates the system. To explore this complex non-equilibrium system, we employ straightforward mathematical models. This research examines a three-lane non-equilibrium system with limited resources and coupling, using the totally asymmetric simple exclusion process (TASEP). This mathematical model studies particle movement along a one-dimensional lattice, where each site is either occupied by a particle or left empty. Our model, inspired by multi-lane biological transport systems, comprises three parallel lattices interconnected by a coupling rate. We apply mean-field theory to investigate how coupling rates influence system behavior in the presence of limited resources. To validate our theoretical predictions, we perform extensive Monte Carlo simulations. The study uncovers several novel mixed phases, bulk-induced phase transitions, and the occurrence of a double shock.

Keywords: Mathematical model, TASEP, Monte Carlo simulations.