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Optimal Control Analysis of Cyberattacks in Software-Defined Networking

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Abstract

This research explores the dynamics of cyberattacks in Software-Defined Networking (SDN) environments using optimal control theory. It aims to study the dynamics of cyberattack propagation in a complex system such as a telecoms/computer network built on the principle of SDN. The focus of the study is to formulate optimal defense strategies to ameliorate the impacts of the cyberattacks with the SDN. The study examines the mechanisms driving the spread and evolution of cyberattacks within SDN architectures using the theory of epidemiology. It considers factors such as attack vectors, propagation pathways, reproduction number, and bifurcation analysis with time delay. The study proposes a model that incorporates delay to represent the latent period, and the basic reproductive number is derived. To evaluate the impact of control measures, the model is reformulated as an optimal control problem incorporating the quarantined class of nodes and mitigation strategies. The existence of an optimal control solution is also demonstrated. Finally, numerical simulations are conducted to validate the theoretical analysis. Additionally, by using time delay as a bifurcation parameter, it is shown that a critical delay value exists for the stability of attack prevalence. If the delay surpasses this critical value, the system becomes unstable, leading to a Hopf bifurcation.

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