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Effect of terminal boundary protection on the spread of computer viruses: modeling and simulation

Key words: Campus network terminal security; Spread of computer virus; Model; Analogue simulation; Terminal protection measures

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Introduction

- Characterized by high bandwidth, wide coverage, intensive information interaction, and many users, the campus network has become an indispensable part of academic and campus life.
- Computer viruses such as Trojan horses, malware, and worms spread quickly in the campus network, over a wide range, and with strong hidden and destructive characteristics.
- Most universities do not have a deeper level to explore the cross-spread characteristic of computer viruses in the campus network.

Tendency, challenges, and motivation

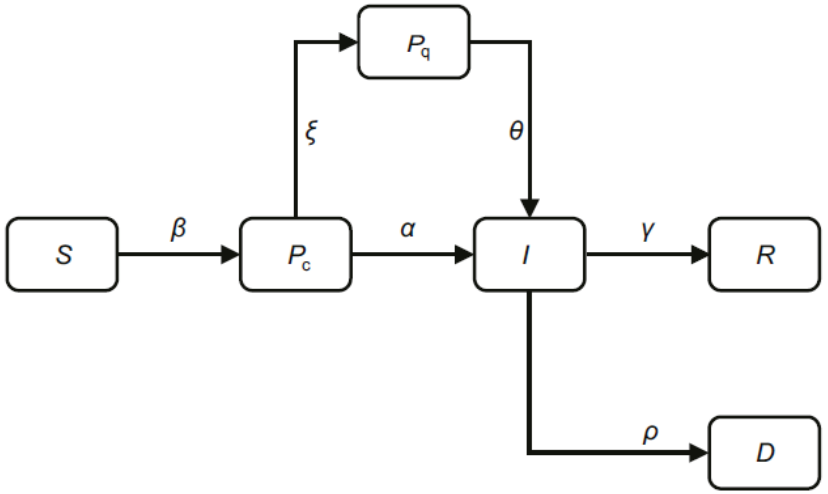
- The diversity and complexity of the user population on the campus network increase the risk of computer virus infection during terminal interactions. Therefore, it is crucial to explore how computer viruses propagate between terminals in such a network.
- A novel computer virus-spreading model based on the characteristics of the basic network structure and a classical epidemic-spreading dynamics model, adapted to real-world university scenarios.
- Analyze the spreading trend of computer viruses in the campus network in terms of the proposed computer virus spreading model.
- Propose specific measures to suppress the spread of computer viruses in terminals, ensuring the safe and stable operation of the campus network terminals to the greatest extent.

Definition of the spread model

- Among the six groups, some susceptible individuals will first transition into the unisolated latent group due to failure to deploy security protection strategies in advance. Subsequently, a portion of the unisolated latent group progress to the infection group due to the lack of network security awareness and other factors, and a portion of the unisolated latent group will transition into the isolated latent group due to the timely deployment of security protection strategies. The isolated latent group is not safe; for instance, the isolated latent group infected with high-risk computer viruses may turn into the infection group. The infection group will progress to the recovery group if the anti-virus measures are successful; otherwise, the infection group will move to the crash group.

$$\begin{cases} \frac{\mathrm{d}S(t)}{\mathrm{d}t} = -\beta S(t)P_{\mathrm{c}}(t), \\ \frac{\mathrm{d}P_{\mathrm{c}}(t)}{\mathrm{d}t} = \beta S(t)P_{\mathrm{c}}(t) - \alpha P_{\mathrm{c}}(t) - \xi P_{\mathrm{c}}(t), \\ \frac{\mathrm{d}P_{\mathrm{q}}(t)}{\mathrm{d}t} = \xi P_{\mathrm{c}}(t) - \theta P_{\mathrm{q}}(t), \\ \frac{\mathrm{d}I(t)}{\mathrm{d}t} = \alpha P_{\mathrm{c}}(t) + \theta P_{\mathrm{q}}(t) - \gamma I(t) - \rho I(t), \\ \frac{\mathrm{d}R(t)}{\mathrm{d}t} = \gamma I(t), \\ \frac{\mathrm{d}D(t)}{\mathrm{d}t} = \rho I(t), \end{cases}$$

$$N = S(t) + P_{\mathrm{c}}(t) + P_{\mathrm{q}}(t) + I(t) + R(t) + D(t),$$

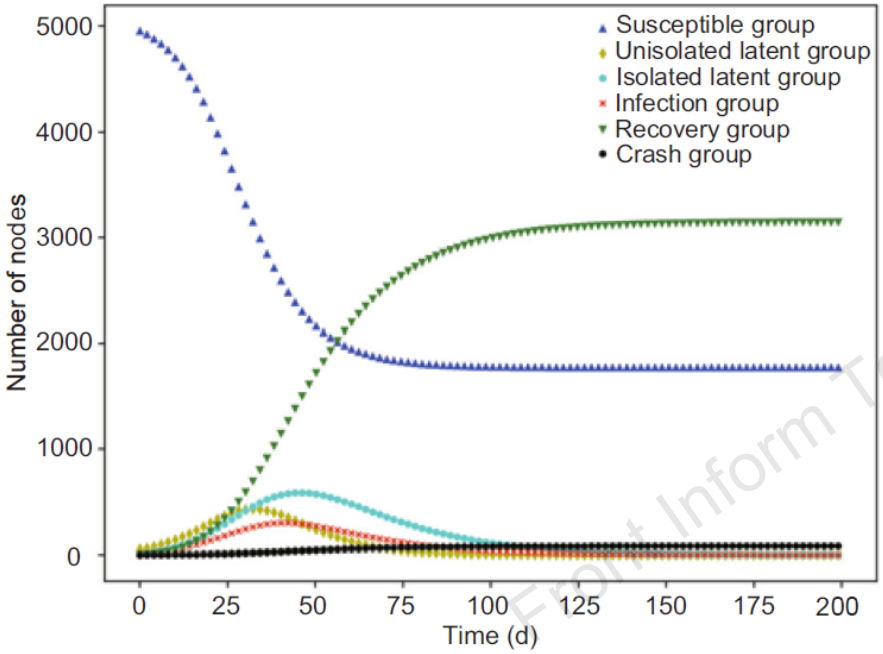


Stability analysis of the spread model

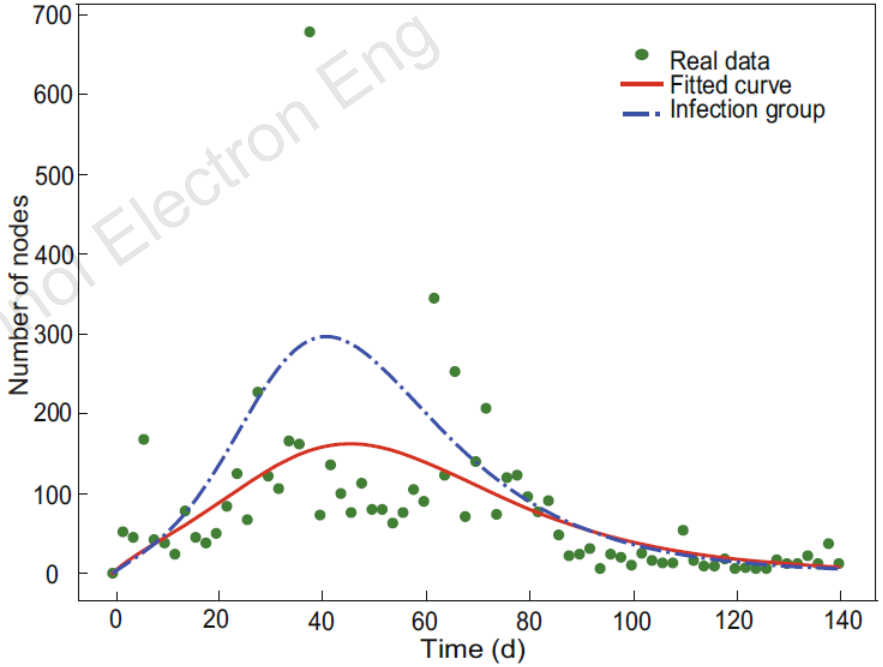
- The determination of the basic reproduction number of the spread model and the proof that the disease-free equilibrium point has local asymptotic stability strengthen the credibility of the model.

$$R_0 = \frac{(\alpha + \theta)\langle k^2 \rangle}{(\gamma + \rho)\langle k \rangle}.$$

Experiments

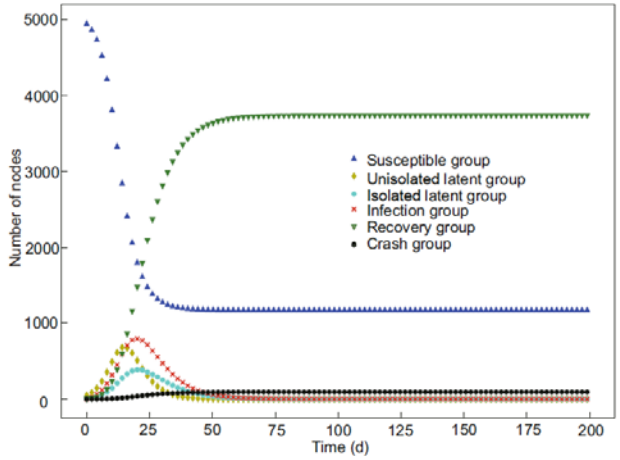


Number of nodes varies with time when $G(i|j) \approx 0.005$, $K(i|j) \approx 0.925$, and $U(i|j) \approx 0.744$

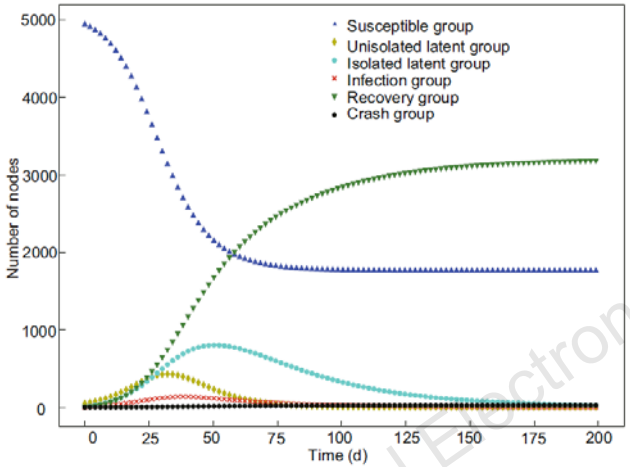


Comparison of the fitted curve to real-world data and the trend of the infection group when $G(i|j) \approx 0.005$, $K(i|j) \approx 0.925$, and $U(i|j) \approx 0.744$

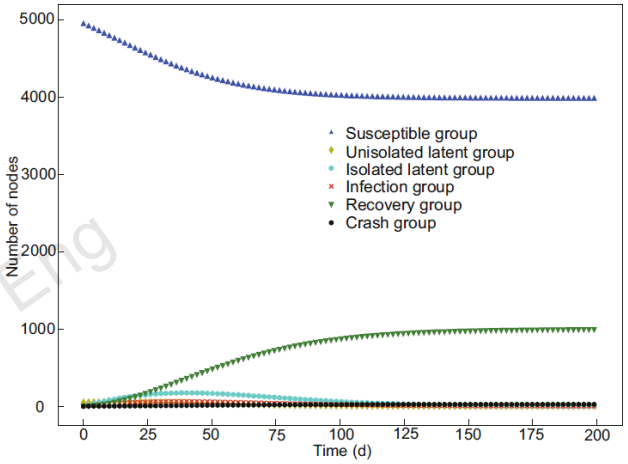
Experiments



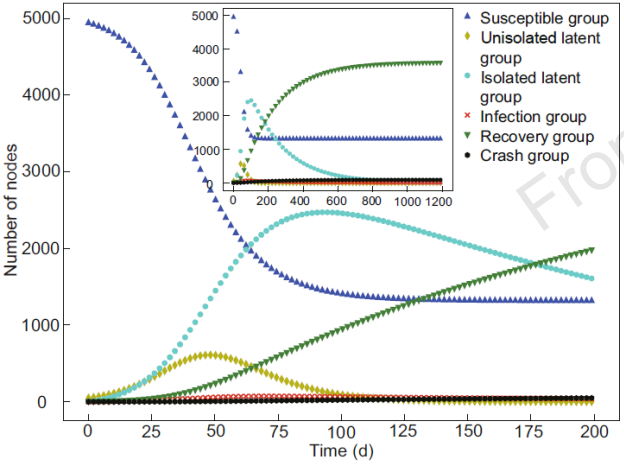
Number of nodes varies with time when $G(i|j) = 0.01$



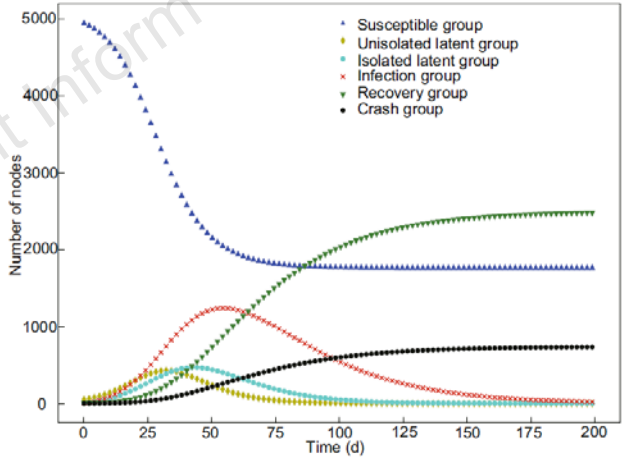
Number of nodes varies with time when $K(i|j) = 0.975$



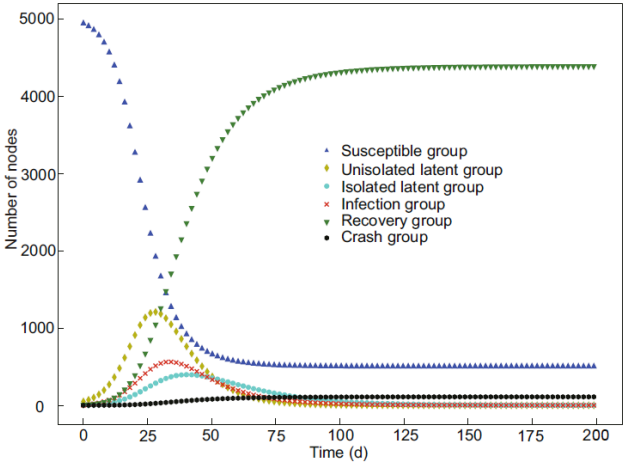
Number of nodes varies with time when $U(i|j) = 0.844$



Number of nodes varies with time when $G(i|j) = 0.001$

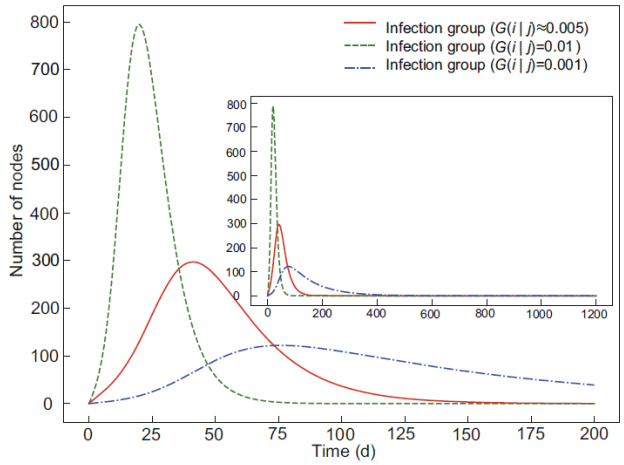


Number of nodes varies with time when $K(i|j) = 0.875$

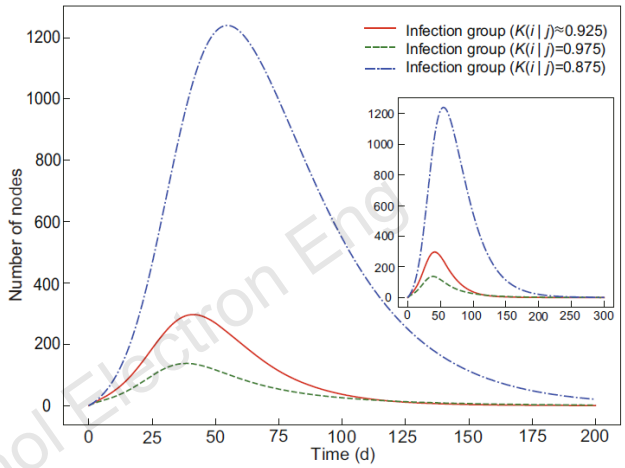


Number of nodes varies with time when $U(i|j) = 0.644$

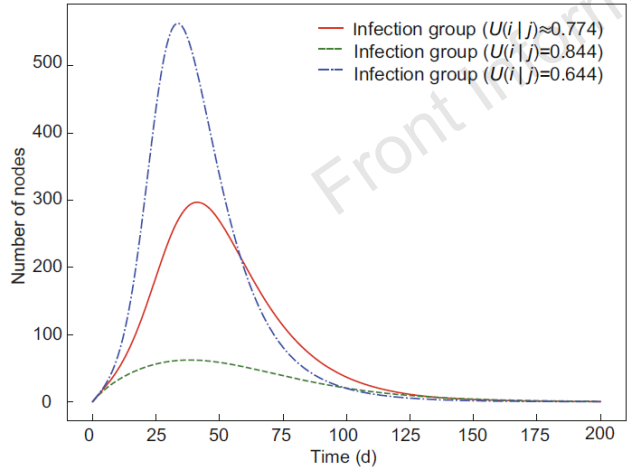
Experiments



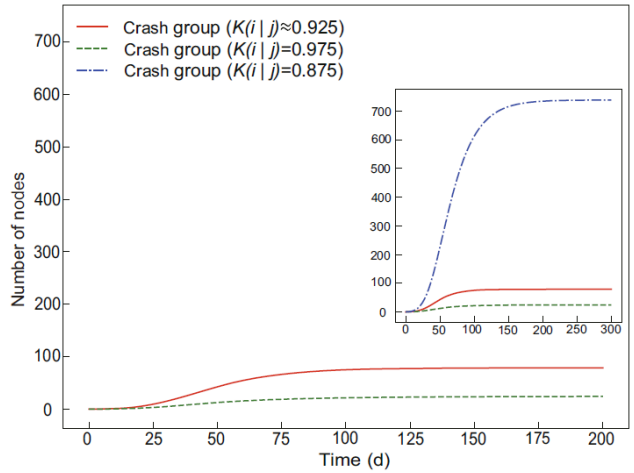
Comparison of the number of nodes in the infection groups over time with different $G(i|j)$'s



Comparison of the number of nodes in the infection groups over time with different $K(i|j)$'s



Comparison of the number of nodes in the infection groups over time with different $U(i|j)$'s



Comparison of the number of nodes in the crash groups over time with different $K(i|j)$'s

Future outlook

- The focus of real data collection in future work could involve larger and more complex metropolitan area network (MAN) and wide area network (WAN) environments.

- It is necessary to identify the interaction among the factors, further improve the mathematical equations and models, and improve the applicability value of the model.

Author biography

Fuzhong Nian received his B.S. degree from the Department of Physics, Northwest Normal University, Lanzhou, China, in 1998, M.S. degree from Gansu University of Technology, Lanzhou, China, in 2004, and Ph.D. degree from Dalian University of Technology, Dalian, China, in 2011. His research interests lie at the intersection of mathematical modeling, network science, and control theory, with applications to biological, social, and chaotic networks.

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