Virus Propagation Behavior Simulation Based on Node Movement Model of Wireless Multi-hop Network

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Abstract

The improvement of communication technology and the popularity of wireless networks bring us a convenient life, but at the same time they provide a new room for the propagation of viruses, which challenges the security of the Internet. In order to deal with the new kind of virus propagation in wireless multi-hop networks, this study used MATLAB simulation software to simulate SI virus propagation model and random path point model and analyze the effects of the time required for virus transmission, the communication radius of nodes and the number of initial infected nodes on the transmission of SI virus in wireless networks. The result showed that the velocity of node movement could affect the velocity of virus transmission which increased first and then decreased with the increase of node moving speed; the virus transmission speed decreased with the increase of the time required for transmission, and increased with the increase of the communication radius of nodes and the number of initial infected nodes; when the propagation speed was the fastest, the movement speed of the corresponding node was inversely proportional to the time required for propagation, directly proportional to the communication radius, and unrelated to the number of initial infected nodes.

Keywords: Node Movement Model; Virus Transmission Model; Wireless Multi-Hop Networks

1 Introduction

After entering the 21st century, information technology has developed fast, so wireless communication technology gradually replaces wired communication technology [5] and popularizes, especially, the emergence of smart phones, iPad and laptops, which further promote the existence of wireless networks. In wireless multi-hop networks [4], people can obtain resources by using mobile terminals as nodes to access the Internet anytime and anywhere, or as base stations to provide resources. The network is open, besides users and operators, users and users can also provide corresponding services, and they can enter different wireless networks at the least cost; the distribution of the network makes it possible for the network to jump to the rest of the intact nodes normally, even if some of the nodes are missing, to obtain the resources on the Internet. However, it is the open and distributed structure of the wireless multi-hop network [20], which poses a severe challenge to network security. Because of the openness, the network virus camouflaged can freely enter the network, and because of the distributed structure, the transmission of the virus is more complex [2, 8, 11, 12, 16, 19].

In order to guarantee the healthy development of the wireless network, it is necessary to strengthen the defense of the network virus and to study the transmission behavior of the network virus [1, 9, 18]. Lu *et al.* [10] used a random approach to study the evolution and impact of the mobile botnet which was a collection of malicious nodes caused by mobile malware that could perform coordinated attacks. It was discovered that the mobility of a node might be a trigger for a botnet propagation storm. Increasing network bandwidth was an aid to mobile services, but at the same time it was possible to increase the risk that the service was being destroyed by the mobile botnet. Han *et al.* [6] discussed the definition and characteristics of the computer virus, analyzed the virus propagation model and the virus control, proved the necessary and sufficient condition of the non-viral equilibrium point and the local disease equilibrium point of the model by the first method and the disc theorem of the Lyapunov, and then calculated the optimal control strategy of the virus propagation model, which verified the effectiveness of the optimal control.

Sanum *et al.* [15] proposed a mobile Ad Hoc wireless network deterministic node mobility model based on chaos, which realized the deterministic process of randomness generation in mobile mode. The simulation results included the moving path of nodes. Comparing the random speed, direction and average speed of the mobile node under certain control parameters, the method could simulate the mobile mode of real users in a controllable way. In this study, MATLAB simulation software was used to simulate SI virus transmission model and random route point model. The impact of the transmission time, node communication radius and initial infective node number of SI virus on the communication in the network were analyzed.

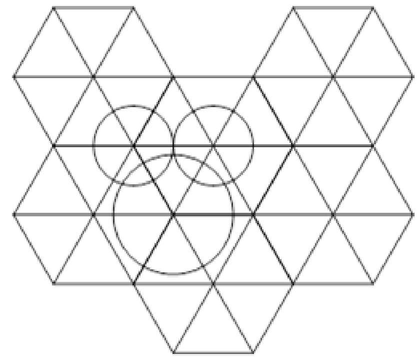

Figure 1: Wireless network topology structure

2 Node Movement Model

Since the beginning of the 21st century, the communication technology has been rapidly improved, from the initial wired communication to the wireless communication which has been widely used, the network constructed by the data interaction is becoming larger and larger, but at the same time the spread of the network virus is also more and more harmful. A wireless multi-hop network consists of multiple nodes, which can be served by a fixed computer or a mobile terminal [3, 14]. Nodes and nodes are connected wirelessly, and data are transmitted to each other through the network. Each wireless node has the function of receiving and transmitting at the same time, and the data in the network jump from one node to the other. Unless all nodes in the network are down, the data must be available to transfer to the target node. The topology of wireless multi-hop networks is not only stable but also extensible. The network node of the original wired communication is limited by the fixed base station, and the network topology of the node [13] will not change, which means the law of the network virus in the transmission process is easy to grasp. However, after the popularization of the wireless communication, the nodes of the wireless network will move with the mobile terminal, and the topology of the network will also change and present irregularity in a short period of time. Therefore, when studying the law of transmission of modern network virus, the movement of nodes needs to be considered.

As shown in Figure 1, the initial network structure in this paper was like that of a cellular network when simulating the propagation law of network viruses. Each intersection point was a network node, and the circle represented the signal coverage range of the node [7]. On the basis of the initial deployment, the node mobility model was added to make the network nodes move within a specified range according to the model rules.

The model of node movement could reflect the law of node movement. The definition of the model could be divided into two types: One was the reproduction of real trajectory, which was reproduced by collecting the moving data of real nodes, but the data that need be processed was too large, which had no extensive practicability; the other was to construct an abstract model, which extracted the motion rules and built a mathematical model by moving data of some real nodes. Random path model (RWP) was one of the most frequently used abstract models in mobile network research. Its principle was Brownian motion. The definition of RWP model [17] was as follows:

1) All nodes were in the rectangular region, and the connection between nodes and nodes was like honeycomb as shown in Figure 1.

2) The nodes moved to any node in the region.

3) The moving speed of the node was within a certain range, and the speed was uniform before reaching the target node.

At the same time, in order to prevent the nodes from leaving the experimental area in the process of random motion, the method of crossing inversion [21] was used to control the motion range and number of nodes. The specific operation was as follows: When any node moves to the boundary of the region, the node was separated from the region from the boundary, and then entered the experimental area again in the symmetrical direction.

3 Virus Transmission Model

The advance of wireless communication technology not only facilitates people's life, but also increases the risk of network security where the network virus is one of the biggest. Its propagation law study can help raise the network security. The transmission mode of network virus in the network is similar to that of the virus in biology. Therefore, according to the characteristics of the transmission of network virus, the transmission model of network virus was constructed with reference to the transmission model of biological virus [25]. At present, there were three common models of virus transmission: SI, SIS and SIR. This paper focused on the SI model [23].

As shown in Figure 2, in the SI model, a node had two shapes: One was the susceptible node "S" (similar to the susceptible population) and the other was the infected node "I" (the equivalent of the source of infection) which represented the probability of a node changing from "S" to "I" within a certain time range, and its formula [24] was expressed as:

$$dS(t) = -\beta I(t)S(t)dt$$
$$dI(t) = \beta I(t)S(t)dt.$$

$S(t)$ represents the proportion of susceptible nodes at the moment, and $I(t)$ represents the proportion of nodes infected at time. Since the immune mechanism was not set in this model, the infected node would not be re-converted to the easy-to-sense node, and eventually the nodes in the entire network would become Class I nodes.

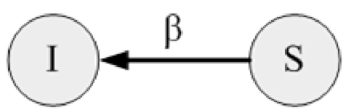

Figure 2: SI virus transmission model

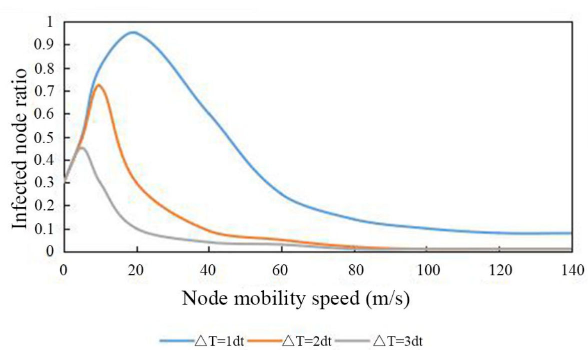

Figure 3: The relationship between node mobility speed and the proportion of infected nodes at time $t = 48s$ under different virus transmission time

4 Simulation Analysis

4.1 Experimental Environment

This paper used the MATLAB simulation platform [22] to compile the network virus propagation model and node moving model. The experiment was carried out on the laboratory server. The server was configured as Windows7 system, I7 processor, 16G memory.

4.2 Experimental Setup

1) Parameter setting of the effect of virus propagation time on the speed of propagation.
Area of node simulation motion region was $\Omega = 1500 \times 1500m^2$; total number of nodes was N=300; number of initial infected nodes was n=3; node communication radius was $r = 30m$; detection time was $t = 48s$. Under the settings of the above parameters, the node infection ratio at different node moving speeds was respectively simulated when the virus transmission time ΔT was 1 dt, 2 dt and 3 dt.

2) Parameter setting of influence of node communication radius on propagation speed.
Area of node simulation motion region was $\Omega = 1500 \times 1500m^2$; total number of nodes was N=300; number of initial infected nodes was n=3; virus transmission time was $\Delta T = 2dt$; detection time was $t = 48s$. Under the setting of the above parameters, the infection ratio of nodes at different moving speeds was simulated when the communication radius of nodes was 20 m, 30 m and 40 m, respectively.

3) Parameter Settings of the influence of the number of initial infection nodes on the propagation speed.
Area of node simulation motion region was $\Omega = 1500 \times 1500m^2$; total number of nodes was N=300; node communication radius was $r = 30m$; virus transmission time was $\Delta T = 2dt$; detection time was $t = 48s$. Under the settings of the above parameters, when the number of initial infected nodes (n) was 3, 6 and 9, respectively, the infection ratio of nodes at different moving speeds was simulated.

4.3 Experiment Results

1) The effect of virus propagation time on the speed of propagation.
As shown in Figure 3, as a whole, as the time was required to spread the virus increases, the speed of infected nodes decreased at the same speed of node movement. The reason was that at a certain node speed, the communication time between nodes could be limited, as the shorter the transmission time was, the greater the probability of successful infection within the communication time and the higher the proportion of infected nodes at would be. Horizontal comparison showed that the speed of the infected nodes increased with the moving speed of the nodes under the transmission time of each virus, which increased first and then decreased. The reason was that with the increase of the moving speed of the nodes, more frequent contact between infected nodes and uninfected ones leaded to an increase in infection rate.

The smaller ΔT was, the faster it would be. When the node moved more than a certain value, although the node contacted more frequently, the communication time between the nodes became shorter, therefore, it was difficult to meet the need of virus transmission time, which made that the probability of infection and the speed of infection decreased. The node moving speed corresponding to the maximum speed of an infected node was called v_{max}. When the time required to spread the virus was 1 dt, v_{max} was

20 m/s; when the time required was 2 dt, v_{max} was 10 m/s; and when the time required was 1 dt, v_{max} was 5 m/s, from which it could be seen that with the time taking to spread the virus, v_{max} decreased because the largest communication times between two nodes were determined by the communication radius and the speed at which the nodes move, so the relationship between the virus spread time and v_{max} was $v_{max} \propto \frac{1}{\Delta T}$.

2) The influence of node communication radius on propagation speed.
As shown in Figure 4, as the node communication radius increased, the infection rate increased at the same node moving speed. The reason was that the increase of communication radius prolonged the communication time between nodes and the virus had more time to complete infection, which leaded to the increase of infection speed.

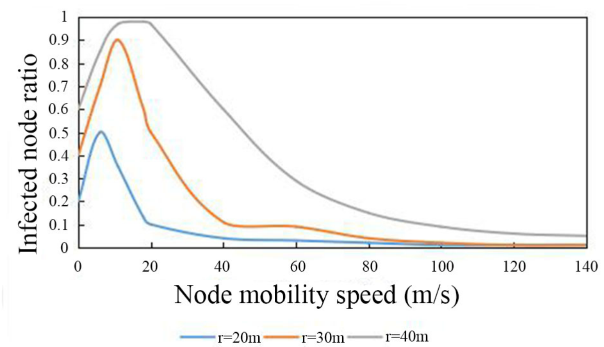

Figure 4: The relationship between node mobility speed and the proportion of infected nodes at time $t = 48s$ under different node communication radius

Horizontally, the speed of infected nodes increased first and then decreased with the increase of node moving speed under every kind of node communication radius. As mentioned above, the increase of node mobility increased the connectivity of nodes. The infection probability increased, the communication time decreased and the infection probability decreased when the speed was too large. At the same time, the larger the communication radius were, the faster the infection speed increased but the slower it decreased. When the communication radius was 20/m, v_{max} was 6 m/s; when the communication radius was 30/m, v_{max} was 11m/s; when the communication radius is 40/m, v_{max} was 18 m/s, and it could be found out that with the increase in the radius of communication, v_{max} increased which was because of an increase in the radius of the virus, and even if the speed of movement increased, it could be guaranteed that the virus would complete the transmission when the communication time was sufficient, so that the relationship between the node communication radius and v_{max} was $v_{max} \propto r$.

3) The effect of initial infective nodal points on the speed of transmission.
As shown in Figure 5, with the increase of initial infected nodes, the infection speed increased with the same node moving speed. The reason was that the increase of initial infected nodes increased the frequency of contact between infected nodes and susceptible nodes, and the probability of successful transmission of the virus increased, which leaded to the increase of infection speed.

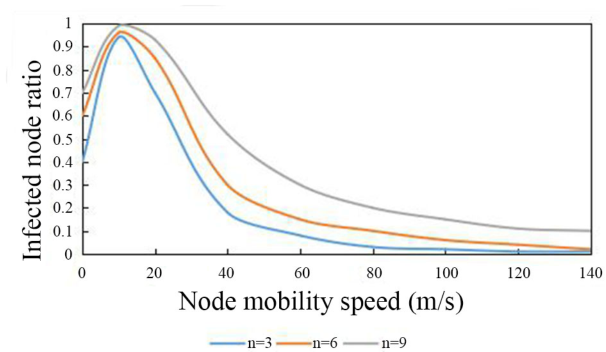

Figure 5: The relationship between node mobility speed and the proportion of infected nodes at time $t = 48s$ under different initial number of infected nodes

Transverse comparison showed that with the increase of node moving speed, the infection node velocity increased first and then decreased with the number of initial infected nodes. As the reason was mentioned above, the more the initial infected nodes were, the faster the infection velocity increased and the slower the infection speed decreased. Whether the initial number of infected nodes was 3, 6 or 9, the corresponding v_{max} were all 10 m/s, from which it could be noticed that v_{max} remained steady with the change of initial infected nodes. The reason was that the infection probability of nodes was related to the network connectivity and the time required to spread the virus. As the network connectivity was an inherent attribute of the network, it was only related to the communication radius and the moving speed of the nodes, and whether the nodes were infected or not would not affect the network connectivity. The transmission time was the attribute of the virus itself, and the nodal infection would not affect the virus itself. In this experiment, the communication radius and propagation time were fixed, so v_{max} would have no change.

5 Conclusion

In this study, SI virus transmission model and RWP model were simulated by MATLAB simulation software, and the effects of virus transmission time, node communication radius and initial infective node number on the transmission of SI virus in wireless network were analyzed. The results showed that:

1) The infection speed of the virus in the network increased first and then decreased with the increase of the moving speed of the nodes.
2) With the increase of the time required for virus transmission, the infection rate of the virus in the network decreased.
3) With the increase of the node communication radius, the infection speed of the virus increased, and the infection speed was the most rapid.
4) With the increase of the initial number of infected nodes, the infection speed of the virus increased, and the corresponding node movement speed did not change at the fastest speed.

In this paper, the biological virus transmission model is applied to the transmission of network virus, and the RWP model is used to simulate the movement of people. Compared with the analysis method of real trajectory reconstruction, this method requires less computation and has higher accuracy.

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Biography

Weimin Kang, born in June 1972, graduated from Jilin University with a master's degree. Her research direction is computer application technology, and she is currently working as an associate professor at Changchun Medical College. She published Computer Basic Examination Reform in Medical Colleges in 2013, Computer Application Fundamentals and Test Analysis in 2014, Opinions on the Development of Health Information Management in China, and Design of the Expert System for Computer Rank Examination Based on J2EE in 2015, Application of Information Retrieval and Information Statistics in Hospital Information System in 2016, How to Use the Use of Disease Codes in Medical Records to Unify Medical Charges in 2017 and Study on the Practical Teaching System of Health Information Management Based on Post Competence in 2019. She held the subject of Computer Level Examination Tutoring Teaching Expert System Based on Artificial Intelligence Technology in 2014, Application Research of "2+3" High-level Talents Training Program for Health Information Management Major in 2016 and international disease classification coding and surgical coding in the application of medical records in 2017.

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