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Assessment of the System's Epi-resistance Under Conditions of Information Epidemic Expansion

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The paper deals with the process of information epidemics spreading in an information and telecommunication system (ITCS) according to the SIR model. Constructing a probabilistic analysis model of information epidemic spreading is carried out; we propose an approach for estimating damage parameters, use and ITCS epi-resistance at different development stages of the process, depending on the model parameters. We provide recommendations for managing ITCS epi-resistance by changing parameters of the model.

Key words: Information epidemics, SIR model, epi-resistance.

Epidemic models as a potentially effective solution of the information spreading problem in ITCS becomes more and more popular. The aim of the information epidemics research is to some extent connected with spreading of other information harmful effects such as DDOS-attacks[1], viruses spreading in social networks[2]. Some studies allow estimating the ITCS component resistance to harmful effects[3]. All these works[1-3] consider rather specific methods and approaches to harmful effects, and so in this article we propose a more general approach to estimating the potential of information malware based on constructing epidemiological models, which provide not only scalability, but also presentation of the description process. However, attackers may also use these algorithms in order to spread harmful information.

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The main part

The amount of damage that an attacker causes to ITCS, directly depends not only on parameters of the system and malware, but also on the presence of antivirus system and the effectiveness of responding to the attack as well as taking measures for eliminating the consequences of harmful effects[4]. Hence, assessment and management of the epi-resistance system and modelling of the process of implementing information epidemic is an urgent task.

For this purpose, we use a simple SIR-model according to which the system elements can refer to one of the following sets.

1. S[i] – a set of elements, which are susceptible to receiving malicious data. S [i] – the number of such elements at the i-th iteration process of infection.
2. I[i] – the set of elements, which can spread malicious data to sensitive objects. I[i] – the number of infected elements at the i-th iteration.

3. R[i] – the set of elements that are completely freed from harmful information and invulnerable to subsequent harmful effects, with which they were infected before[3]. R[i] – the number of recovered elements at the i-th iteration.

Furthermore, in ITCS there is a number of elements that are not susceptible to this epidemic (M). Such elements do not pass to different states. All uninfected elements will be considered healthy (Q). We will denote virus significant parameters as follows:

a) N – total number of elements in the system, it is a given parameter, constant in the examined process of the epidemic and does not have probabilistic nature;
b) n – average number of elements in direct contact with each element;
c) b- average probability of the system element infection by malicious information;
d) r – probability that the elements pass to the state of not susceptible elements and receive immunity to infection;
e) Δt – time of sampling process model. There are several approaches to the choice of Δt. According to the first option we may choose infection time as this time, in this case, the parameter r must be selected taking into account the cure probability for the infection period. In the second option, we can take as Δt the time interval, which is much smaller than the minimum time from the times of infection or treating, in this case, r and β must be calculated for the selected time interval.

The article deals with ITCS with roughly the same average number of connections between the elements. This approximation is valid in cases of examining processes of epidemiological infection in peer-to-peer networks[5], where the parameter n is large enough.

Let the process of information epidemic begin with infection of a single element, in this case at every stage of the process only uninfected elements will be subject to the effects, and infected items will recover only from the effect of L-th order of development. Let us consider the mathematical expectation as the primary measure of chance and risk and construct an algorithm (Table 1) for their calculation (estimation).

The number of infected and recovered elements in this case is[5, 6]:

$$I[m] = \frac{(\beta \cdot n)^m - 1}{\beta \cdot n - 1},$$

$$R[m] = \frac{r \cdot ((\beta \cdot n)^{m-l} - 1)}{\beta \cdot n - 1},$$

$$S[m] = \sum_{i=1}^{m} n^i = \frac{n^m - 1}{n - 1}$$

Thus, the average damage from the viral insecurity of elements for ITCS in normalized form will amount to[7]:

$$\Pi(m) = \frac{I[m] - R[m]}{S[m]} = \frac{\frac{(\beta \cdot n)^m - 1}{\beta \cdot n - 1} - \frac{r \cdot ((\beta \cdot n)^{m-l} - 1)}{\beta \cdot n - 1}}{\frac{n^m - 1}{n - 1}} = \frac{((\beta \cdot n)^m - r \cdot ((\beta \cdot n)^{m-l} - 1))(n-1)}{(n^m - 1)(\beta \cdot n - 1)}$$

The above function can be regarded as a risk measure of a virus epidemic during the stage m of viral infection, taking into account the delayed antivirus work. Hence the usefulness of virus protection (a measure of chance) will be[8-10]:

$$\bar{v}(m) = \frac{Q[m] + R[m]}{S[m]} = \frac{\frac{((1-\beta) \cdot n)^m - 1}{(1-\beta) \cdot n - 1} + \frac{r \cdot ((\beta \cdot n)^{m-l} - 1)}{\beta \cdot n - 1}}{\frac{n^m - 1}{n - 1}} =$$

$$= \frac{((1-\beta) \cdot n)^m - 1)(\beta \cdot n - 1) + r \cdot ((\beta \cdot n)^{m-l} - 1))((1-\beta) \cdot n - 1)(n-1)}{(n^m - 1)((1-\beta) \cdot n - 1)(\beta \cdot n - 1)}.$$

Then we can find the ratio:

$$L_v(m) = \frac{\bar{v}(m)}{\bar{u}(m)} = \frac{\frac{((1-\beta) \cdot n)^m - 1}{(1-\beta) \cdot n - 1} + \frac{r \cdot ((\beta \cdot n)^{m-l} - 1)}{\beta \cdot n - 1}}{\frac{n^m - 1}{n - 1}} \times$$

$$\times \frac{\frac{n^m - 1}{n - 1}}{\frac{(\beta \cdot n)^m - 1}{\beta \cdot n - 1} - \frac{r \cdot ((\beta \cdot n)^{m-l} - 1)}{\beta \cdot n - 1}} =$$

$$= \frac{((1-\beta) \cdot n)^m - 1)(\beta \cdot n - 1) + r \cdot ((\beta \cdot n)^{m-l} - 1))((1-\beta) \cdot n - 1)(n-1)}{((1-\beta) \cdot n - 1)((\beta \cdot n)^m - r \cdot ((\beta \cdot n)^{m-l} - 1)(n-1))}.$$

Epi-resistance – a parameter of the epidemic information, which reflects the ability of the system anti-virus restore elements to the working condition:

$$L_v(m) = \frac{R[m]}{S[m]} = \frac{\frac{r \cdot ((\beta \cdot n)^{m-l} - 1)}{\beta \cdot n - 1}}{\frac{n^m - 1}{n - 1}}.$$

In the case when ITCS contains M elements, not susceptible to this type of harmful effects, the average number of susceptible elements in direct contact with each element is reduced by

M', and functions of damage and benefits will take the following form:

$$\Omega(m) = \frac{I[m] - R[m]}{S[m]} = \frac{\frac{(\beta\cdot(n-M))^m - 1}{\beta\cdot(n-M)-1} - \frac{r\cdot((\beta\cdot(n-M))^{m-1}-1)}{r\cdot\beta\cdot(n-M)-1}}{\frac{(n-M)^m-1}{n-M-1}} =$$

$$= \frac{((\beta-\beta n+\beta M)^m-1)(r-r\beta+r\beta n-r\beta M-1)-(\beta(n-M)-1)(r(\beta-\beta n+\beta M)^{m-1}-1)}{((n-M)^m-1)(\beta-\beta n+\beta M-1)(r-r\beta+r\beta n-r\beta M-1)},$$

$$\Phi(m) = \frac{Q[m] + R[m]}{S[m]} = \frac{\frac{((1-\beta)\cdot(n-M))^m - 1}{(1-\beta)\cdot(n-M)-1} + \frac{r\cdot((\beta\cdot(n-M))^{m-1}-1)}{r\cdot\beta\cdot(n-M)-1}}{\frac{(n-M)^m-1}{n-M-1}},$$

$$\Psi(m) = \frac{(((1-\beta)\cdot(n-M))^m-1)(r-r\beta+r\beta n-r\beta M-1)+r\cdot((\beta\cdot(n-M))^{m-1}-1)((1-\beta)\cdot(n-M)-1)(n-M-1)}{((n-M)^m-1)((1-\beta)\cdot(n-M)-1)(r-r\beta+r\beta n-r\beta M-1)}$$

Let us consider the development model of information epidemic in which the spread of infection begins with a single element. In this case, we will start from the worst case, in which at each stage of the process only uninfected and unrecovered elements will be subject to the effects with a probability of infection p_{fi}=0.33, and infected elements will be recovered with the coefficient p_{rec}=0.2. The average number of connections for each element n=5, and the anti-virus system for the considered information epidemic begins to operate only from the 6th stage of the epidemic. Then the epi-resistance of the system for m=10 is equal to $L_f(10) = 347$.

$$L_f(m) = \frac{\Phi(m)}{\Omega(m)} = \frac{\frac{((1-\beta)\cdot(n-M))^m - 1}{(1-\beta)\cdot(n-M)-1} + \frac{r\cdot((\beta\cdot(n-M))^{m-1}-1)}{r\cdot\beta\cdot(n-M)-1}}{\frac{(n-M)^m-1}{n-M-1}} \times$$

$$\times \frac{\frac{(n-M)^m-1}{n-M-1}}{\frac{(\beta\cdot(n-M))^m-1}{\beta\cdot(n-M)-1} - \frac{r\cdot((\beta\cdot(n-M))^{m-1}-1)}{r\cdot\beta\cdot(n-M)-1}} =$$

$$= \frac{(((1-\beta)\cdot(n-M))^m-1)(r-r\beta+r\beta n-r\beta M-1)+r\cdot((\beta\cdot(n-M))^{m-1}-1)((1-\beta)\cdot(n-M)-1)(n-M-1)}{((\beta\cdot(n-M))^m-1)(r-r\beta+r\beta n-r\beta M-1)-(\beta\cdot(n-M)-1)\beta\cdot((\beta\cdot(n-M))^{m-1}-1)}$$

Thus, thanks to the system the owner gets 347 times more benefits than damage caused by the implementation of the information epidemic on the SIR model.

The resulting function of the epi-resistance has three parameters with which it is possible to affect on it: r,β,n. By adjusting them, it is possible to affect the objective function the epi-resistance.

In order to simplify the analysis of the function of the epi-resistance we transform it into a more convenient form:

$$L_f(m) = \frac{r(1-\beta)(\beta\cdot n)^m n - r(\beta-1)n - r(\beta n)^m + r + \beta n(n(1-\beta))^m - \beta n - ((1-\beta)n)^m + 1}{n(1-\beta)(\beta n)^m(1-r) - (\beta n)^m(1-r) - n(1-\beta)(1-r) + 1 - 2r}.$$

However, the effectiveness of changing one or another parameter of the system at different times and in different states of the model is not the same. The first task of managing the epi-resistance is to determine the parameter to be changed to achieve the desired level of protection.

To solve this problem we apply the optimization algorithm of gradient descent.

Sensitivity coefficient of this function to changing the model parameters can be determined using partial derivatives:

$$\frac{dL_f(m)}{dr} = \frac{\beta^m n^{m+1}(1-\beta) - (\beta n)^m - (\beta-1)n + 1}{n(1-\beta)(\beta n)^m},$$

$$\frac{dL_f(m)}{d\beta} = \frac{rn^{m+1}(m\beta^{m-1} - (m+1)\beta^m) - rn - rn^m m\beta^{m-1} + n^{m+1}(1-(m+1)\beta^m) - n + n^m}{n^{m+1}(m\beta^{m-1} - (m+1)\beta^m)(1-r) - n^m m\beta^{m-1}(1-r) - n(1-r)},$$

$$\frac{dL_f(m)}{dn} = \frac{r(1-\beta)\beta^m m n^{m-1} - r\beta - r\beta^m n^{m-1} + \beta(\beta-1)^m(m+1)n^m - \beta - (1-\beta)\beta^m m n^{m-1}}{(1-\beta)\beta^m(m+1)n^m(1-r) + \beta^m m n^{m-1}(1-r) + (\beta-1)(1-r)}$$

As a result, the control function can be presented as the gradient function:

Table 1. Assessment of elements state depending on the stage of development of information epidemic on the SIR model with delayed work of an anti-virus subsystem

Stage of infection	Number of healthy elements Q[i]	Number of infected elements I[i]	Number of recovered elements R[i]
1	$(1-\beta)n$	βn	–
2	$(1-\beta)(1-\beta)nn$	$\beta n\beta n$	–
-	-	-	-
l	$(1-\beta)^l n^l + r\beta^l n^l$	$\beta^l n^l - r\beta^l n^l$	$r\beta^l n^l$
-	-	-	-
m	$(1-\beta)^m n^m + r\beta^m n^m$	$\beta_{\square}{}^m n^m - r\beta^m n^m$	$r\beta^m n^m$

$$\nabla L_f(\mathbf{m}) = \left(\frac{dL_f(\mathbf{m})}{dr}, \frac{dL_f(\mathbf{m})}{d\beta}, \frac{dL_f(\mathbf{m})}{dn}\right)$$

The next task is to choose the direction in which management of the epi-resistance function will occur. It is advisable to choose the direction in which the derivative function has maximum value, so we can achieve the required level of epi-resistance.

Let us assume that it is necessary to change epi-resistance for $\Delta L_f(m)$, for that purpose we need to calculate this divergence function of the model on the m state, we determine the direction of the optimal control and then depending on this choice, we calculate the required change of the model parameter using one of the formulas:

$$\begin{cases} \Delta r = \dfrac{dL_f(\mathbf{m})}{dr} \cdot \Delta L_f(\mathbf{m}); \\ \Delta \beta = \dfrac{dL_f(\mathbf{m})}{d\beta} \cdot \Delta L_f(\mathbf{m}); \\ \Delta n = \dfrac{dL_f(\mathbf{m})}{dn} \cdot \Delta L_f(\mathbf{m}). \end{cases}$$

CONCLUSION

Thus, in this paper we considered a very urgent innovative task of ITCS protection from viral effects. We proposed a fundamentally new approach to calculating epi-resistance and survival rates of the system, taking into account the presence of unsusceptible elements, in which the epidemic develops on the SIR model starting from infecting one element, and the recovery starts with the effect of the i-th order with a delayed work of the antivirus. We modelled the process of sharing information epidemic under different initial parameters, which ultimately reduces the risk of spreading harmful information in ITCS.

REFERENCES

1. Ostapenko, A.G., S.S. Kulikov, N.N. Tolstykh, Y.G. Pasternak and L.G. Popova, Denial of Service in Components of Information Telecommunication Systems through the Example of "Network Storm" Attacks. *World Applied Sciences Journal*, 2013; **25**(3): 404-409.
2. Ostapenko, G.A., L.V. Parinova, V.I. Belonozhkin, I.L. Bataronov and K.V. Simonov. Analytical Models of Information-Psychological Impact of Social Information Networks on Users. *World Applied Sciences Journal***, 25**(3): 410-415
3. Ostapenko, G.A., D.G. Plotnikov, O.Y. Makarov, N.M. Tikhomirov and V.G. Yurasov, Analytical Estimation of the Component Viability of Distributed Automated Information Data Systems. *World Applied Sciences Journal* 2013; **25**(3): 416-420.
4. Kalashnikov, A.O., Y.V. Yermilov, O.N. Choporov, K.A. Razinkin and N.I. Barannikov, Ensuring the Security of Critically Important Objects and Trends in the Development of Information Technology. *World Applied Sciences Journal*, 2013; **25**(3): 399-403.
5. Kuniya, T., Global stability analysis with a discretization approach for an age-structured multigroup SIR epidemic model: Nonlinear Analysis: *Real World Applications*, 2011; **12**: 2640-2655.
6. Yermilov, E.V. and A.O. Kalashnikov, Technique of information risk management of attacked automated control systems of critically important facilities resistance to virus attacks on network structures based on risk assessment. Voronezh: Voronezh State Technical University, Journal "*Information and Security*", 2013; **16**(Part 3): 379-382.
7. Rytov, M.Y. and O.M. Golembiovskaya, Identification of malicious software on the basis of the analysis of virus signatures using neural networks. Voronezh: Voronezh State Technical University, *Journal "Information and Security*", 2013; **16**(Part 3): 407-410.
8. Ivankin, E.F., S.V. Mashin and N.I. Barannikov, Analytical assessment of information risk of virus attacked automated systems. Voronezh: Voronezh State Technical University, *Journal "Information and Security"*, 2013; **16**(3): 463-465.
9. Radko, N.M., L.V. Parinova, Y.G. Pasternak, K.A. Razinkin, N.M. Tikhomirov, Pervasive viral attacks on distributed information systems: generalized risk assessment models of epidemics and chances of an effective response. Voronezh: Voronezh State Technical University, *Journal "Information and Security"*, 2013; **16**(4): 500-501.
10. Radko, N.M., LV. Parinova, Y.G. Pasternak, K.A. Razinkin, N.M. Tikhomirov, Counteraction to virus attacks on network structures on the basis of risk assessment. Voronezh: Voronezh State Technical University, *Journal "Information and Security"*, 2013; **16**(4): 502-503.