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MODELING AND ANALYSIS OF THE SECURITY SYSTEM INFORMATION IN SERVICE NETWORKS

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Introduction

This article is devoted to the study of the information security system (ISS) from unauthorized access in service networks.

At the same time, problems are considered that are typical for systems with losses, with limited and unlimited buffer memory (BM) [1-3]. In contrast to these works, here we propose an approach to generalizing the considered problems for ISS with losses, with limited and unlimited volume of BM.

The analysis shows that the importance of the problem of information security is recognized, and this is confirmed by the huge losses incurred by corporations due to insufficient information security [4-6].

The current state of the problem in the field of information security and the development of IBS indicates the presence of serious difficulties, which are largely related to the lack of a unified system for assessing information security, which allows to give a quantitative assessment in designing and operating the service network [4-6]. It should be noted that at present, due to the insufficient development of experience in designing information security systems, the tasks of building an ISS should be solved at the early stage of designing a service network [1-3]. At present, given the growing number of scientific papers and companies involved in information security in service networks, this problem remains relevant.

It should be noted that one of the most obvious reasons for violating the ISS is a deliberate request for unauthorized access (UAS) to confidential information by illegal users and subsequent unwanted manipulations with this information [4-7].

The effectiveness of information security protection in service networks is determined mainly by the security class of the service network [8-9], which determines the set of protection mechanisms (PM) implemented in the network. It should be noted that regardless of whether the PM as part of the ISS is a hardware or software part, it can function in constant informational interaction with other elements of the ISS, influencing the entire process of information protection.

In the system, the functioning of the PM is described by possible states such as, serviceable, faulty, diagnosed, restored.

Note 1: In the system, the risk is considered to be the possibility of the occurrence of some unfavorable event associated with the reliability characteristics of the PM, entailing various kinds of losses.

Note 2: In this paper, approaches associated with the risk arising from the characteristics of the reliability of the PM are not considered in this case, since it is assumed [1,2,3]. that all PM are considered reliable.

At the same time, the optimal configurations of the ISS with losses, with limited and unlimited buffer memory volumes, which allow functioning with limited resources (the number of service devices (PM) operating in parallel) are investigated).

At the early stages of design, results are prepared in order to construct the ISS, which are the optimal values of the structural characteristics of the ISS within the allowable loss of requests. Hese characteristics are:

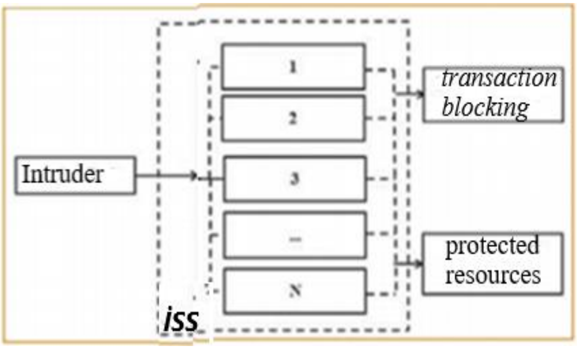
- number of service devices (PM) operating in parallel;
- number of UAS requests in the system;
- waiting time for UAS requests in the queue;
- residence time of UAS requests in the system.

In [1-3], due to the existence of the fact of incomplete closure by the protection system of all possible channels for the manifestation of threats, the ISS structure was proposed, i.e., in contrast to the structures [8-9], all input streams get the PM for servicing.

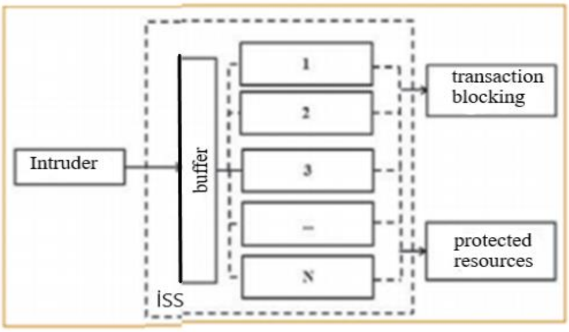
The papers propose a lossy ISS structure (without a buffer) [1], with limited [2] and unlimited [3] buffer memory, which ensures maximum information security of service networks by ensuring control over the transition of all UAS requests through the PM.

ISS from UAS is a hardware-software complex that interacts with streams of random events that are caused by the actions of intruders, incorrect distribution of access rights, use of unauthorized software, errors in software and hardware complexes of identification, authentication [1-3,9-10].

In contrast to [1-3], in order to generalize the problems under consideration, the problem of ISS analysis is solved here for mixed systems of enclosing systems with losses (fig.1a), with limited (fig.1b) and unlimited (fig.1c) buffer memory. Consequently, the problem arises of determining the optimal configuration of the ISS, which ensures the maximum degree of information security of service networks by ensuring control over the transition of all requests for UAS through the PM.



a)



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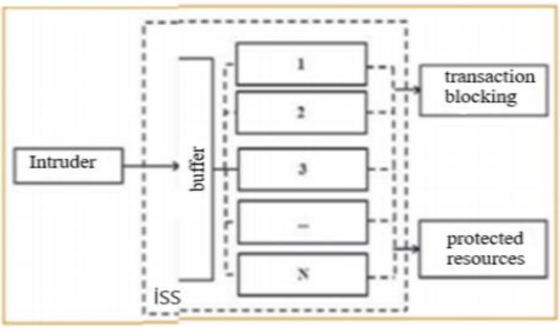

c)

Fig. 1. The structure of the information security system. a) systems with losses, b) systems with limited buffer memory, c) systems with unlimited buffer memory

In the proposed structures, the intruder (intruder, UAS requests) at the input of the system creates various threats with intensity λ.

Mixed-type queuing systems (QS) are considered as a mathematical model of the ISS, which include:

- systems with losses (systems without waiting in line);
- systems with a limited amount of buffer memory (with a limited waiting time in the queue);
- systems with an unlimited amount of buffer memory (with unlimited waiting time in the queue).

In all these cases, if one of the PM is free, then the UAS request arrives at this free PM, at which the initial UAS stream is rarefied with certain probabilities and forms an output stream.

In a system with losses, in the case of occupancy of all MP, the UAS request is lost. And in systems with limited and unlimited buffer memory, in the case of occupancy of all PM, the UAS request waits in a queue in the system buffer memory until one of the PM is freed if there is free space in the buffer memory.

The aim of the work is to develop a mathematical model of the ISS as a mixed-type QS, which makes it possible, due to the limited resources available, to determine its optimal characteristics. If we consider the intruder's block as a source of information, and the PM as parallel operating devices, then the ISS can be considered as a single-phase multi-channel mixed-type queuing system, i.e., lossy system with limited and unlimited buffer memory (fig.1a, 1b, 1c).

ISS consists of N – the number of PM that carry out service delays$\tau_0 = 1/\mu$, where μ – the intensity of servicing requests for UAS.

During maintenance, UAS requests are screened out. In the ISS, using the PM, detection with a certain probability and classification of UAS attempts are performed, and the functions of blocking or skipping UAS requests to protected resources are implemented. Missed (unrecognized) requests can harm protected resources. Protected resources do not perform independent access control functions.

The paper seeks the optimal configuration of the ISS, allowing functioning with limited resources.

It is assumed that the input flow of information, i.e., UAS requests, are the simplest, and the service time (ST) is subject to exponential, constant and Erlang distribution laws.

At the same time, it is required to determine the optimal values of the number of service devices (PM) operating in parallel, the number of UAS requests in the ISS, the residence time of UAS requests in the ISS within the allowable loss of UAS requests resulting from waiting in the queue.

As an efficiency criterion, minimization of the mathematical expectation of the probability of loss of UAS requests in the ISS with the structure under consideration was chosen.

Statement of the problem and algorithm for analyzing the characteristics of a system with losses, with limited and unlimited buffer memory

The general statement of the problem of determining the optimal characteristics of a system with losses, with bounded and unbounded expectations in [1-3] is formulated as follows:

$$M[P(\lambda,\mu,\mathrm{N})] \rightarrow min \qquad (1)$$

at $\lambda \geq \lambda_0, \mu \geq \mu_0, N \geq N_0$,

$L_q \leq L^0$.

where M – is the sign of the mathematical expectation, $P(\lambda,\mu,N)$ – is the probability function of losing UAS requests from failure due to service system overload, L_q – is the average value of the queue length, i.e., the value that determines the amount of buffer memory, $\lambda_0, \mu_0, N_0, L^0$ – admissible limit values.

In [1-3] it is noted that there is currently no single rigorous analytical expression $P(\lambda,\mu,N)$ that allows calculating the loss of UAS requests with limited, unlimited expectations and losses, and the analytical solution of problem (1) is very difficult.

Therefore, problem (1) in [1] is solved for a system with bounded expectation (i.e., for an ISS with a limited buffer), in [2] it is solved for a system with losses (i.e., for an ISS without a buffer), and in [3] solved for a system with unlimited wait (i.e., for ISS with unlimited buffer).

At the same time, as a function of loss of UAS requests due to system overload, in [1-3], respectively, for these cases, the Poisson formula, the Erlang loss function and the Erlang delay function (2)-(4), are used:

$$P_1(\lambda,\mu,N) = (\rho^N /[(N-1)!(N-\rho)] / \\ / [\sum_{k=0}^{N-1}\rho^k / k! + \rho^N /[(N-1)!(N-\rho)] \quad (2)$$

$$P_2(\lambda,\mu,N) = \sum_{j=N}^{\infty}(\rho^j / j!)e^{-\rho} \quad (3)$$

$$P_3(\lambda,\mu,N) = (\rho^N / N!) / \sum_{k=0}^{N}(\rho^k / k!) \quad (4)$$

where$\rho = \lambda/\mu$ – is the reduced intensity.

It should be noted that a strict analytical expression for determining losses $P(\lambda,\mu,N)$ in this case, i.e., there is currently no mixed-type QS and, therefore, the analytical solution of statement (1) is very difficult.

At the same time, for $\rho > 0, N = 1,2,3,\ldots$ between (2)-(4) there is the following relation [11]:

$$P_1(\lambda,\mu,N) > P_2(\lambda,\mu,N) > P_3(\lambda,\mu,N) \quad (5)$$

Relation (5) in a normalized form can be an indirect solution of the problem (1).

Note that normalization means choosing from the set of values P_1, P_2, P_3 only those under which the condition$L_q \le L^0$ is satisfied for the number of requestsL_q waiting for service for different service time distributions, whereL^0 – is the maximum allowable queue length in any time slice, i.e. a value that determines the amount of buffer memory.

Thus, with relation (5) and the fulfillment of the condition, the considered mixed-type QS provides servicing of the flow of requests within the limits of permissible losses and, therefore, the system has the minimum required performance.

To study ISS as single-phase multi-line QS of a mixed type, an algorithm is proposed for obtaining the optimal values of system characteristics. This algorithm is a generalization of the proposed algorithms in [1-3]. It differs in that the functions are used as functions of the probability of losing UAS requests in the ISS, and the service process is terminated when the average value of the queue length satisfies the condition $L_q \le L^0$, where $0 \le L^0 < \infty$.

Using this condition, the proposed algorithms are used to search for the optimal characteristics of the ISS. And after the conditions $L_q \le L^0$are met. the obtained characteristics are accepted as the optimal characteristics of the ISS. The algorithm includes the following steps.

At the first step, after entering the average values λ, μ and setting the initial value $N = N_0$, the loss of requests is determined by (2)-(4). At the next steps, the number of UAS requests in the queue is determined L_q, and the relation (2)-(4) is normalized for three cases of analytical analysis of the system characteristics.

1. The intensity of receipt and service time of requests obey the exponential law. At the same time, for the exponential service time [12]:

$$L_q = (\rho^{N+1} /[(N-1)!(N-\rho)] / [\sum_{k=0}^{N-1}\rho^k / k! + \rho^N [(N-1)!(N-\rho)]$$

Depending on the nature of the object at $\rho \rightleftarrows\rightleftarrows << 1, L_q \to \rho^{N+1}/N^2$ and at $\lambda/\mu N \to 1$, $L_q \to \rho/(N-\rho)$.

If the condition $L_q \le L^0$ is satisfied, the process is considered normal, so the obtained characteristics are displayed, and the analytical analysis is completed.

Otherwise, the analysis continues and the transition to the second case is carried out.

2. The intensity of the receipt of requests is subject to an exponential law, and the service is constant (deterministic). If the condition $L_q \le L^0$ is not satisfied, the system should expand its capabilities by $N = N + 1$, and if satisfied, it should make the transition to the third case. For constant service time [12]:

$$L_q = \rho \sum_{m=1}^{\infty} e^{-m\rho}[(1 - N/\rho) \sum_{n=mN+1}^{\infty} (m\rho)^n / n! + (m\rho)^{mN} / (mN)!]$$

3.The fulfillment of the conditions $L_q \leq L^0$according to the constant service law may turn out to be insufficient to take into account some other requirements for the system, for example, reliability.

Therefore, an analytical analysis of the characteristics of the system is additionally carried out for the Erlang service time [12]: $L_q = \rho^2(1 + 1/k)/(2(1 - \rho),$

where parameter $k = \overline{1, \infty}$.

For the Poisson system, one can use [12]:

$$L_q \approx [1 + 0{,}0830 (\frac{k-1}{k+1})^{0{,}944} (N-1)^{0{,}674} ((1-a) + $$
$$+ 0{,}974 N^{0{,}937} k^{0{,}0254} (1-a)^{2{,}04})] (k+1)\rho^2 / 2k (1-\rho)$$

where $a = \lambda/\mu N$, for large values a:

$$L_q \approx [1 + \frac{1}{12}(\frac{k-1}{k+1})(N-1)^{2/3}((1-a) +$$
$$+ (1-a)^2)](k+1)\rho^2 / 2k(1-\rho)$$

After determining, L_q it is possible to determine the waiting time for UAS requests in the queue $\tau_q = L_q/\lambda$, the residence time of UAS requests in the system, $\tau_s = L_s/\lambda, a < 1$, the expected number of UAS requests in the system $L_s = L_q + \rho$.

Note that the fulfillment of the condition for $L_q \leq L^0$ is sufficient to complete the analysis. If this condition is not met, the transition to the first case of the algorithm is carried out at $N = N + 1$.

Numerical experiments

On the basis of real data of oil and gas production objects, as an example, for average values $\lambda = 1/1400$мс, $\mu = 1/2498$мс, and $L^0 = 1$ the Poisson flow of requests for UAS, according to the proposed algorithms and compiled programs, volumetric computational experiments were carried out and obtained numerical results for exponential, constant and Erlang service times.

Based on the results obtained fig.2 and fig.3 show the dynamics of the decrease in the length of the request queue in the UAS $L_q = f(N)$ and the dynamics of the decrease in the probability functions of losing requests of the UAS in the ISS for 1-exponential, 2-constant and 3-Erlang service times at $N = 2\ldots5$.

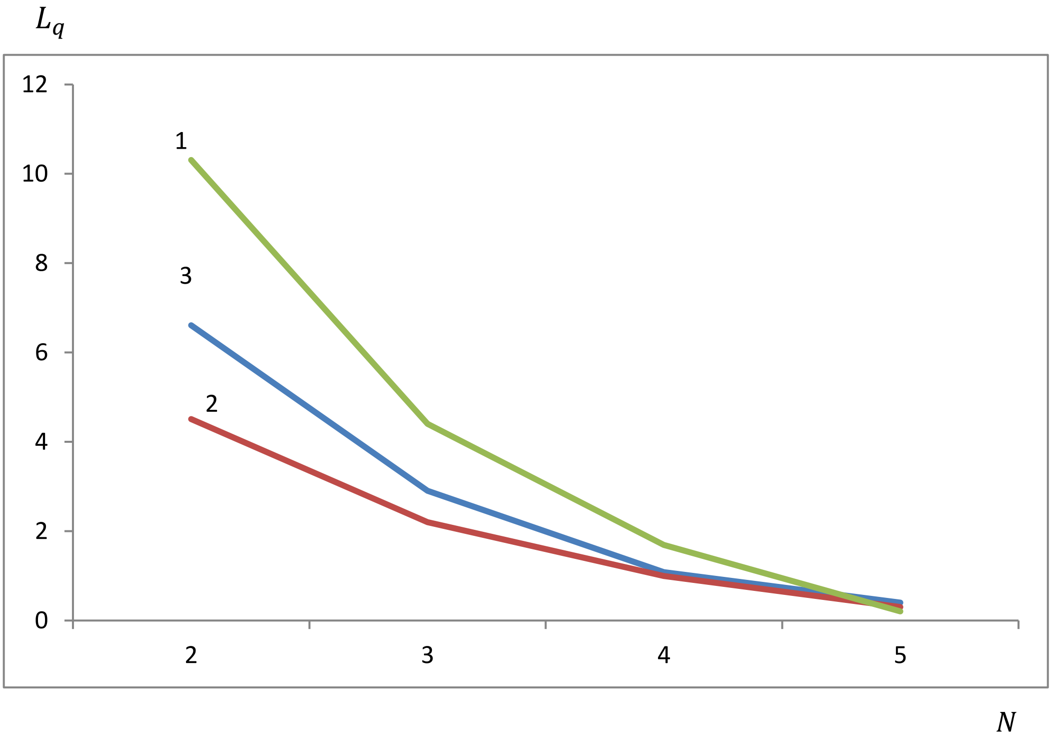

Fig. 2. Dependence $L_q = f(N)$ for 1-exponential, 2-constant, 3-Erlang ST, $N = 2\ldots5$.

Analysis of the obtained results (fig.3) shows that the condition $L_q \leq 1$ for all three service time distributions is satisfied, i.e., ratio values:

$$P_1(\lambda, \mu, N) > P_2(\lambda, \mu, N) > P_3(\lambda, \mu, N)$$

are satisfactorily normalized only for $N \geq 4$.

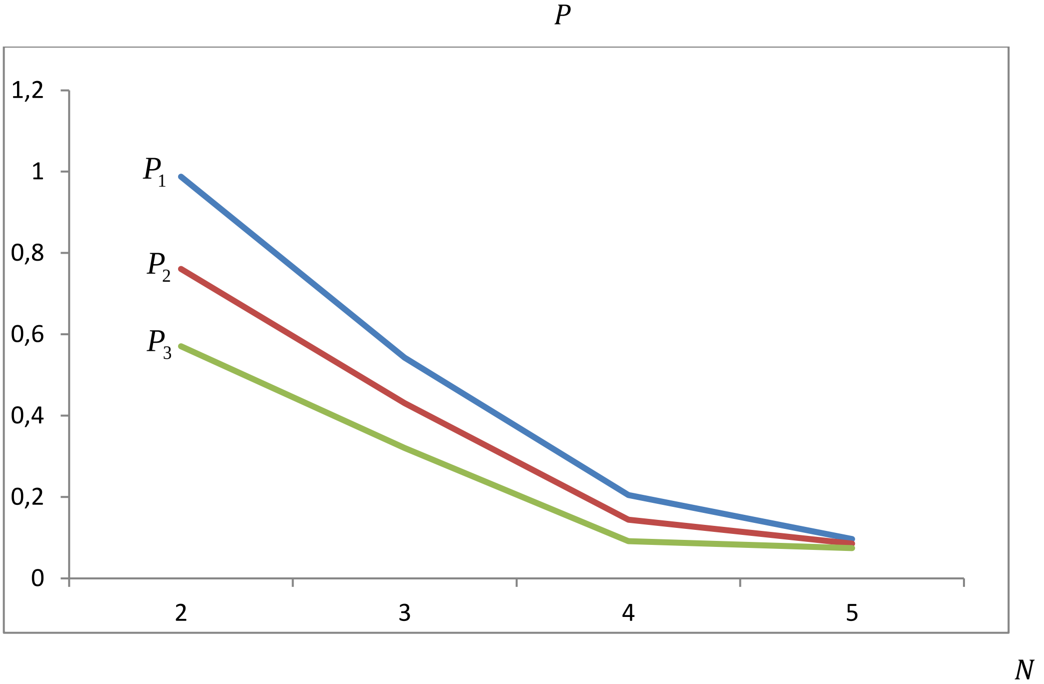

Fig. 3. Dependency $P = f(N)$ for P_1 - exponential, P_2 - constant, P_3 - Erlang ST, $N = 2\ldots5$.

Then, $L_q = f(N)$ dependencies can be used to select specific values of the parameters and characteristics of the system (fig.2).

The condition $L_q \leq 1$ for all three service time distributions is satisfied only for $N \geq 4$ (fig.3).

Checking the adequacy of the analytical results, as well as a detailed analysis of the characteristics of the ISS with losses, with limited and unlimited buffer memory for exponential input, exponential, constant and Erlang output flows for their various values, taking into account their complexity, was carried out on the basis of the developed simulation models in the language GPSS (General purpose simulation system).

The model considers a single-phase multi-channel mixed-type QS, in which Poisson input streams are supplied for service, and the transaction service time obeys exponential, constant, and Erlang distribution laws.

In the model, when a transaction enters the system with losses, if all the PM are busy, the transaction is lost. And in systems with limited and unlimited buffer memory volumes, if all PM are occupied, the transaction waits in a queue in the system buffer memory until one of the PM is freed, if there is free space and if there is a free service device (PM), the transaction receives service.

Three runs of calculations on the simulation model were carried out. The obtained results show that for three cases of analysis, taking into account all transactions and in the presence of an acceptable number of transactions in the queue at the input of the ISS, the instrument utilization factor (PM) is 0.952; 0.861; 0.772 respectively.

In other words, service devices (PM) do not stand idle, i.e., they are loaded within the limits, i.e., Satisfactory service is going on in ISS.

Comparative analysis of the results of the analytical model with the results of the simulation model shows that they are well matched and the deviation of these results is within the acceptable range of 2...7%. The results obtained can be used in modifying existing or building new ISS in service networks for oil and gas production facilities.

Conclusions

The paper proposes computational procedures and algorithms for analyzing the optimal values of the parameters of the ISS as a single-phase multichannel mixed-type QS. Numerical experiments have been carried out and results have been obtained. In order to check the adequacy of the obtained results, simulation experiments were carried out, confirming the adequacy of the numerical results. These results can be used in the construction of new or modification of existing ISS in the service networks of oil and gas production facilities.

This work is an approach to the generalization of the considered problems for systems with losses, with limited and unlimited buffer memory.

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MODELING AND ANALYSIS OF THE SECURITY SYSTEM INFORMATION IN SERVICE NETWORKS

The optimal setting of the information security system (ISS) is determined as a system of increasing service with loss, with an unlimited amount of buffer memory, expanding the use of computing network security by transferring all unauthorized access flows (UAF) from the protection mechanism (PM). Computational procedures and algorithms have been developed to study the optimal characteristics of the ISS as single-phase multichannel queuing systems (QS) with losses, with a limited and unlimited buffer size. Computational experiments have been *carried out and numerical results have been obtained, which allow them to be used in the construction of ISS in the service network of oil and gas facilities.*

Keywords: *information security system, systems with losses, with limited and unlimited buffer memory, protection mechanism, unauthorized access, queuing systems, service time.*

Ісмайлов Б.Г.

МОДЕЛЮВАННЯ ТА АНАЛІЗ СИСТЕМИ БЕЗПЕКИ ІНФОРМАЦІЇ У МЕРЕЖАХ ОБСЛУГОВУВАННЯ

Визначається оптимальна конфігурація системи безпеки інформації (СБІ), як системи масового обслуговування з втратами, з обмеженим та необмеженим обсягом буферної пам'яті, що забезпечує максимальну інформаційну безпеку мереж обслуговування шляхом забезпечення переходу всіх запитів несанкціонованого доступу (НСД) від механізму захисту (МОЗ)). Розроблено обчислювальні процедури та алгоритми дослідження оптимальних характеристик СБІ як однофазних багатоканальних систем масового обслуговування (СМО) з втратами, з обмеженим і необмеженим обсягом буферної пам'яті. Проведені обчислювальні експерименти і отримані чисельні результати, які дозволяють використовувати їх при побудові СБІ в мережах обслуговування об'єктів нафтогазовидобутку.

Ключові слова: *системи безпеки інформації, системи з втратами, з обмеженим та необмеженим обсягом буферної пам'яті, механізм захисту, несанкціонований доступ, системи масового обслуговування, час обслуговування.*