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TASKS AND METHODS OF THE STATIC OPTIMUM ENCODING OF SERVICE REQUEST RELATIVE PRIORITIES IN THE INFORMATION PROTECTION SYSTEM OF LOCAL AREA NETWORK

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Summary. The alternative methods of the optimum encoding of relative priorities of requests and methods of their change on schedule to provide the functioning of the information protection system in a local area network in real time are examined. Tasks, criteria of optimality and methods of synthesis of static codes unalterable in time or in the process of system functioning come into a question.

Key words: information protection system, local area network, alternative methods of the optimum encoding of relative priorities of requests.

THE PROBLEM STATEMENT

Modern control systems in dynamic subject areas, such as business management, automated information systems of enterprises, social networks, Internet databases and many others must be adaptive and changeable according to the working conditions. The change of these working conditions, on the one hand, is related to the change of business process of the system and, on the other hand, depends on the change of environment which includes the evolution of external surroundings, change of strategies and tactic of opposite actions etc.

Application of computers in a control system of the state and commercial structures demands a presence of modern systems of the information processing. The solution of this problem has led to the creation of numerous corporate information systems. Their use has allowed the users having computers and access to the network to get access to the information of databases of enterprises, banks, etc. It allows in turn to carry out operatively the most complicated calculations, to communicate fast with other respondents in the network regardless of distance.

ANALYSIS OF PRECEDING RESEARCHES.

But such systems have involved a number of problems, one of which was the safety of data processing and transmission. Especially the most "defenceless" were the data transmitted in local and global telecommunication networks.

To realize these possibilities in perspective control information systems it is necessary to provide a dynamic conduct, autonomy and adaptation of separate components, to use methods, based on the multicomponent systems and (or) autonomous calculations.

In this work the approach to research adaptive mechanisms of functioning of intellectual agents commands is offered on the example of protecting from computer attacks "Distributed Denial of Service" (*DDoS*) in a network. These attacks are realized by plenty of programming agents. The basic task of protection consists of exact identification of attacks, rapid reacting on them, recognition of legitimate traffic which is mixed with the attack traffic and traffic delivery to the purpose of the attack. Adequate protection can be attained only by co-operation of great number of the distributed components.

The task of adaptation is presented in great numbers articles. For example, a model for dynamic adaptation in real time is presented in [1]. The basic principles of autonomous calculations (self-restoration, self-configuration, self-optimization and self-protection) are described, for example, in [5].

The most important researches are works on vitality and stability to the threats. These researches focus on addition to the existing computer systems the mechanisms of adaptive protection. In many systems, steady to encroachments, a capacity for automatic adaptation (auto adaptations) is standard [4]. In [1] the approach based on the use of intermediate software (middleware) is presented, which allows an appendix and basis network infrastructure to react to attacks on the basis of protection strategy with certain vitality requirements. The architecture of Willow [4] provides stability to encroachments through combination of three mechanisms: round of disrepairs (on the basis of disconnecting of vulnerable network elements), debugging (by means of replacement of system elements) and stability to the disrepairs (on the basis of reconfiguration of the system).

Offered by different authors [1, 3] the conception of requests maintenance on access to the shareable resources in the computer system with the information protection function or in a local area network (LAN) is based on the realization of service discipline with relative priorities, changeable to on-schedule (including on priority). This approach allows to get original service disciplines for examined appendixes. Offered approach is realized by principles of code control system of subscribers to provide effective access to the resources system.

Purpose of the work is consideration of alternative methods of the optimum encoding of request relative priorities (*A request is a request for implementation of certain work from a subscriber to shareable resource.) and methods of their change on-schedule to provide the functioning of the system in real time. Tasks, criteria of optimality and methods of synthesis of static codes of priorities which are codes not changeable in time or in the process of system functioning come into a question.

Basic material of the article. As the basic quality requirements of construction and functioning of the information protection system (IPS) in real time are implementation of temporal limitations in maintenance of requests dispersed IPS can be described by determined model. Temporal parameters of maintenance of requests are: T_{pm} is duration of resource m, $m = 1,...,M$, is a subscriber for informative cooperation; T_{nnm} is duration of transmission of rights to m subscriber after liberation of resource in the system; $K_{i(m)}$ is a coefficient of frequency of resource an i, $i = 1,...,M$, is a subscriber relatively m, $i \neq m$.

The issue of utilization of feedback algorithms in the information protection systems ADPS (which take into account the presence and size of request queues, the speed of the demand entry, interval between consequent demands, type of demands, etc.) arises under more profound consideration of the so-called cyclic algorithms, where only the information about incoming flow and saturation flows is used. Such control mode (within which the demand thread handling is realized strictly under certain law) is most often used in handling systems with large-scale load when the demand densities in different threads are practically similar. Nevertheless in the case of occurrence of the thread gap (no incoming requests) the cyclic handling method is no longer expedient: for a certain thread the handling device works in the light running mode while there are queue requests for handling on other threads. In such situations it is more rational to apply other handling algorithms which use additional information about the structure of the incoming demand threads. However to implement such algorithms requires the utilization of additional technical means; this entails immediately the appreciation and complication of the system. Consequently there arises a question of working out simpler and more efficient feedback algorithms, which use some minimal system information and have no need in application of intricate facilities.

The suggestion is to consider the threads conflict provided, firstly, it is impossible to sum up certain threads and reduce the task to a one-dimensional case, secondly, the handling of conflict request threads is performed in the non-crossing time intervals, thirdly, there exist the intervals of inaccessibility during which the threads are out of handling.

Presently there remains a poorly explored question of modeling of the handling systems with a variable structure including DPF (data protection facilities) representing the mathematical models of the behavior of objects with incoming demand threads under condition of their conflict nature.

Let us consider the multiserver quetch with the limited capacity pool. In the system there are n identical devices functioning independently one from another and handling the incoming requests of the same type.

Every single DPF device may be situated on one of T , $1 < T < \infty$, handling phases. The request handling time on every single unit is distributed by the law of the phase type with parameters h and A, where h is a row-vector of size T and A is a square matrix of order T . The frequency distribution function of the phase type of the request handling time is written as*:*

$$A(x) = 1 - he^{A\tau}1, \tag{1}$$

where: 1 - column-vector of units, (via 0 - null matrix, and via E - identity matrix).

Should the system receive a request, but all n devices are already used, this request is directed to the pool (queue) of the O_i capacity. As a rule $O > 2$; if the pool is loaded the request being not handled quits the system (is lost). The pool requests are handled in the order of their entering the system. Besides we should designate $R = n + O$.

We consider now the process with the limited set of modes $\{1,2,...,I\}$, $1 \le I < \infty$. Every time the process mode is changed, there is generated a new request ready to enter the handling environment. The probability that the process will switch from mode i immediately to mode j, $i, j = \overline{1, J}$, during the time period less than τ equals $H_{ij}(\tau)$. The average time period between the changes of the process statuses in the steady-state mode may be written as

$$\tau_s = p_a \int_0^\infty \tau \cdot dH(\tau) 1, \tag{2}$$

where p_a is the row-vector of the steady-state probabilities of the imbedded Markov chain;

$H(\tau)$ is the matrix consisting of elements.

Let us dwell upon the steady-state functioning mode of the handling request generation process. During time period $\Delta\tau$ with probability $\xi\Delta$ there takes place the lock-up of the incoming request threads, that means, since this very moment the process-generated requests do not enter the system, but «go lost». The requests being in the system do not quit the latter but continue to be handled (the requests in DPF devices) or to wait for handling (queue requests). If the thread is locked, then for time period $\Delta\tau$ with probability $\lambda\Delta$ the thread will be unlocked and the requests generated thereafter will enter the handling system anew. The request thread generation does not depend upon whether or not the request receipt in the system is blocked.

We will use certain schemes obtained for the multiserver quetch with the limited pool, and namely applying the fact that the handling process performed by all of the DPF devices, on each of these the handling is distributed according to the law of the phase type, can be described as the Markov handling process in the following way.

If there are κ, $0<\kappa<n+O$, requests in the system the handling process can be in one of the z_k, $z_k < \infty$, modes (handling phases), and also the phase change intensity of the Markov process is determined by the elements of matrices L_k, $k = \overline{0, n+O}$, if neither of the requests was handled and by the elements of matrices M_k, $k = \overline{1, n+O}$, if a request was handled. It is supposed that $z_k = z$ with $k = \overline{n, n+O}$ the matrices $L_k = L$ coincide under $k = \overline{n, n+O}$, and matrices $M_k = M$ coincide under $k = \overline{n+1, n+O}$. We will consider matrix $L+M$ indecomposable and matrix M - non-zero.

If there are $k, \quad k=\overline{0,n-1}$, requests in the system we will assume that at the moment of receipt of the next request by the system the fact, to which phase the Markov handling process will switch, is determined by the elements of matrices Ω_k.

We will consider the imbedded Markov chain determined by the moments of the phase change of the request generation process.

Let us call by means of $p^w{}_{ik}$, $w=0{,}1, \quad i=z_k(r-1)+e, r=\overline{1,I}, e=\overline{1,z_k}, k=\overline{0,R}$ the steady-state probability of the fact that there are *k* requests in the system immediately after the change of the process phase, the phase of the semi-Markov request generation process is in phase *r* and the Markov handling process is in phase *e* and if *w* = 0, then the request thread is locked and if *w* = 1, then the request thread is unlocked. Supposing $p_k^w=(p_{1k}^w,...,p_{1z_k,k}^w), p_k=(p_k^0,p_k^1), w=0{,}1, k=\overline{0,n+O}$.

The system of equilibrium equations *p = pG,* where matrix *G* is the the matrix of transition probabilities of the imbedded Markov chain, is true for vector *p.* Matrix *G* can be viewed block-structured:

$$G=\begin{pmatrix} G_{00} & G_{01} & 0 & 0\ldots & 0 & 0 \\ G_{10} & G_{11} & G_{12} & 0\ldots & 0 & 0 \\ \ldots\ldots & & & & & \\ G_{R-1,0} & G_{R-1,1} & G_{R-1,2} & G_{R-1,3} & \ldots G_{R-1,R-1} & G_{R-1,R} \\ G_{R0} & G_{R1} & G_{R2} & G_{R3} & \ldots G_{R,R-1} & G_{R,R} \end{pmatrix}. \tag{3}$$

The methods for solution of the systems of equilibrium equations are outlined in the works [2]. Concerning our model we will introduce the following ratios for matrices Gij, certain additional denotations. Let us call by means of $q_{ij}(\tau), \quad i,j=0{,}1$, the probability of the fact that after time period τ the requests will not enter the handling system (the request receipt will be locked) if j=0, and the requests will enter the system (the request receipt will be unlocked) if j=1, under the condition that at the start time the request receipt is locked if *i=0*, and unlocked if *i=1*. Then it holds true for the following ratios

$$q_{00}(\tau)+q_{01}(\tau)=1 \quad \text{and} \quad q_{10}(\tau)+q_{11}(\tau)=1. \tag{4}$$

Let us find probabilities $q_{ij}(\tau), \quad i,j=0{,}1$.

We will call the Laplace function transformation $q_{00}(\tau)$ as $\hat{q}_{00}(u)$, then

$$\hat{q}_{00}(u)=\int_0^\infty e^{-u\cdot\tau}q_{00}(\tau)d\tau. \tag{5}$$

Supposed, the request receipt is locked at the start time. Then the request receipt will remain locked after time period τ if during time τ the lock-up status was not changed at all or changed even number of times. That is why by reason of independence of the time periods, during which the process of the request receipt remains locked or unlocked the following ratio holds for $\hat{q}_{00}(u)$:

$$\hat{q}_{00}(u) = \frac{1}{u+\lambda} + \frac{\xi \cdot \lambda}{(u+\lambda)^2 \cdot (u+\xi)} + \frac{\xi^2 \cdot \lambda^2}{(u+\lambda)^3 \cdot (u+\xi)^2} + \ldots = \frac{u+\xi}{u \cdot (u+\xi+\lambda)}. \tag{6}$$

It follows that probability $q_{00}(\tau)$ can be found from the ratio

$$q_{00}(\tau) = \frac{\xi}{\xi+\lambda} + \frac{\lambda\xi}{\xi+\lambda} \cdot e^{-(\xi+\lambda)\cdot\tau}. \tag{7}$$

Using the analogous approach we can obtain the formulas for $q_{01}(\tau), q_{10}(\tau), q_{11}(\tau)$, i.e.

$$\begin{aligned} q_{01}(\tau) &= \frac{\lambda}{\xi+\lambda} - \frac{\lambda}{\xi+\lambda} \cdot e^{-(\xi+\lambda)\cdot\tau}, \\ q_{10}(\tau) &= \frac{\xi}{\xi+\lambda} - \frac{\xi}{\xi+\lambda} \cdot e^{-(\xi+\lambda)\cdot\tau}, \\ q_{11}(\tau) &= \frac{\lambda}{\xi+\lambda} + \frac{\xi}{\xi+\lambda} \cdot e^{-(\xi+\lambda)\cdot\tau}. \end{aligned} \tag{8}$$

The peculiarity of functioning of the given system with refusal is that with the similar process- and handling time parameters in the system with the discontinuous thread the load on the device is distinctly less compared to the ordinary system. There fore the lapse of time during which the devices are out of action, not handling requests, serves as a crucially important indicator of functioning of the DPF with discontinuous thread.

Quality of requests maintenance can be described in such way: T_{am} is duration of arbitration of m subscriber requirement (from the moment of appearance of request to the moment of subscriber right to occupy a resource) or latency of request service; T_{om} is duration of request maintenance of the system.

In the real-time systems there are values of the considered descriptions (the worst for any request): T_{rpm}; T_{rnnm}; $K_{ri(m)}$; T_{ram}; T_{rom}; I, $m = 1,\ldots,M$, $i \neq 1$ parameters of requests maintenance in the real-time system: T_{ram}, T_{rom}.

So there is a model of the real-time system:

$$\begin{cases} T_{ram} = T_{rnnm} + \sum_{i=1}^{M} K_{ri(m,i\neq m)} \cdot (T_{rnnm} + T_{rpi}); \\ T_{rom} = T_{rpm} + T_{rnnm} + \sum_{i=1}^{M} K_{ri(m,i\neq m)} \cdot (T_{rnnm} + T_{rpi}); \\ \forall m, m = 1,..., M; \\ T_{rpm} \neq \infty. \end{cases} \quad (9)$$

Statement. Maintenance of request in real-time is correct if the terms are executed for any subscriber of the system *of m*, $m = 1,..., M$ (1).

Proof. If one condition (1) (even for one subscriber of the system) is not executed, it is impossible to consider that his requests are served in real-time, because his parameters of maintenance T_{am} and T_{om} in this case can not be limited from above and, consequently, there will be system operating conditions $T_{ram} < T_{am}$ and $T_{rom} < T_{om}$ or request will be served not in real time, i.e. it is lost for the system.

So a real-time request is a request which will be lost if it will not be served by the system during fixed period of time from the moment of receipt.

Idea of code multiaccess control. These are principles of real-time code control [1, 3, 4].

At any moment of functioning of the information protection system the matrix of subscriber relative priorities (MRP) (a subscriber is an user of shareable resource of the computer system or network) is a matrix of codes of relative priorities (MCP). The lines of MCP correspond to the lines of matrix of priorities (MP) and columns set a RP code of request. An example of MCP supposes that "1" in code word "0" (on "1" rights are passed, on "0" - no) and that priority of code decreases as far as growth of its sequence number, fig. 1.

$$\text{MRP} \qquad\qquad \text{MCP}$$

$$\begin{array}{c|c} & \begin{array}{cccc} j\;1 & 2 & 3 & 4 \end{array} \\ \begin{array}{c} i\\1 \\ 2 \\ 3 \\ 4 \end{array} & \begin{bmatrix} 0 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix} \end{array} \leftrightarrow \begin{array}{c|c} & \begin{array}{cccc} m\;1 & 2 & 3 & 4 \end{array} \\ \begin{array}{c} n\\1 \\ 2 \end{array} & \begin{bmatrix} 1 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 \end{bmatrix} \end{array}$$

Fig. 1. Example of reflection MRP in MCP

2. During every resource change in the process of the system functioning MCP changes according to the change of initial (by replacement MP on MCP in all moments of time t_s, set by the system) which results in the graphics of MCP changing (realization of transmission on-schedule). An example of MCP in case of without priority service (service in a cyclic order) is fig. 2.

$$\begin{array}{ccccccc}
\begin{array}{cc} m & \begin{array}{cccc}1&2&3&4\end{array}\\ n & \\ \begin{array}{c}1\\2\end{array} & \begin{bmatrix}1&1&0&0\\1&0&1&0\end{bmatrix}\end{array} & \rightarrow &
\begin{array}{cc} m & \begin{array}{cccc}1&2&3&4\end{array}\\ n & \\ \begin{array}{c}1\\2\end{array} & \begin{bmatrix}0&1&1&0\\0&1&0&1\end{bmatrix}\end{array} & \rightarrow &
\begin{array}{cc} m & \begin{array}{cccc}1&2&3&4\end{array}\\ n & \\ \begin{array}{c}1\\2\end{array} & \begin{bmatrix}0&0&1&1\\1&0&1&0\end{bmatrix}\end{array} & \rightarrow &
\begin{array}{cc} m & \begin{array}{cccc}1&2&3&4\end{array}\\ n & \\ \begin{array}{c}1\\2\end{array} & \begin{bmatrix}1&0&0&1\\0&1&0&1\end{bmatrix}\end{array} \rightarrow \\
t_1 & & t_2 & & t_3 & & t_4
\end{array}$$

Fig. 2. Example of MCP change

3. The digit-by-digit (since more priority digits) comparison of RP requests codes of necessary resource must be carried out during the control access to the resource with "disconnecting" of every digit of less priority requests; at the synonymous encoding of requests it will be an employment of resource.

Principles of the optimum encoding of RP subscribers. The arbitration of requests is carried out on every RP code digit n_m, $n_m = 1, \ldots, N_m$ (their number makes $[\log_D M]$, where D is a basis of code), where there is a specific expenditure *of* T_{ynm}: this time on a transmission of rights to a subscriber for employment of resource (arbitration) makes

$$T_{rnnm} = N_m \cdot T_{ynm}. \tag{10}$$

The expression (10) determines the alternative ways of diminishing of time T_{rnnm} on code management multi access control with the change of N_m and T_{ynm} parameters. To solve the classical problem on information theory the method of Khaffmen can be used [1]. Alternative approach is a decline of T_{rnnm} losses due to the diminishing of T_{ynm} which is related to the choice of rights transmission mechanism on access to the resource between the subscribers of the system.

The feature of the other task of the optimum RP encoding will be a necessity of account of higher priority of level "1" above the level "0" (it is so set initially) in every digit of RP code, because at value "1" in the digit of priority code a subscriber gets a right to occupy a resource, at value "0" he doesn't. Great number of subscribers with the probability of p requirements of shareable resource of the system identical for all of subscribers is a mathematical model of the even stage-by-stage encoding/decoding (or simply stage-by-stage encoding) of users of shareable resources: $\{M, N, 0 \le p \le 1, m=1, M, n = 1, N\}$. A quantity p is description of intensity of system entering of resource requirements.

The quantity $P_n(p)$ is probability of the synonymous decoding of m subscriber on n from N of code digits of priority at probability of p subscriber to the shareable resource of the system. These are changes of $P_n(p)$ at $n=1; 2; 3$, $P_{n=1,\,2,\,3}(p)$ at the change of p. The dependences $P_n(p) = f(p)$ for the case of $M=8$ are presented on fig. 3, which shows that probability of the synonymous subscriber decoding changes at small loads of the system with the increase of code word, so the method of *N* digits of priority code encoding is surplus (there is an even code), especially at small loads of the system (MATLAB 7).

During the process of subscribers RP encoding the principle of the priority encoding which consists of major subscriber RP encoding by shorter code word can be realized to reduce the access to the resource. Such approach is expedient when it is necessary to take into account the importance of subscribers but it does not give an optimum code as the effective use of resource, because at priorities encoding the stream parameters of resource requirements are not taken into account but the importance of subscribers does. Thus, priority encoding is encoding of priorities of subscribers in the multi access system to the shareable resources. The purpose of this encoding is an account of relative importance of subscribers.

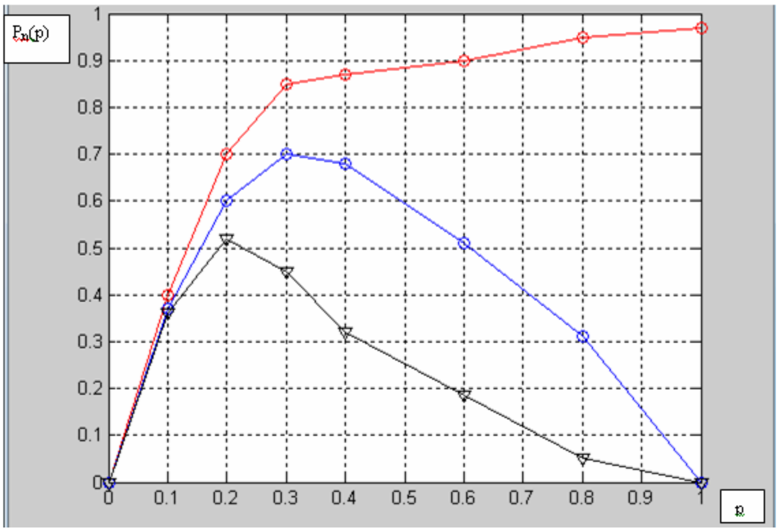

Fig. 3. Illustration of efficiency of the stage-by-stage encoding (MATLAB 7)

Essentially, it is a method of the optimum encoding, but efficiency of the use of resource is determined not by descriptions of input stream of requirements but by possibility of setting of subscriber's real time priorities in accordance with limitations on the time of maintenance of their requests on employment of resource in the system.

The task of the priority encoding is following: there are many subscribers of the system $\{M,\ m = 1,\dots,M\ \}$ with different importance which is necessary to realize the correlations of RP codes lengths N_m $m = 1,\dots,M$. To carry out RP encoding it is necessary to confront the great number of subscribers M with the great number of priorities codes, each of which has the initially set length N_m, providing the synonymous reflection of great number of subscribers to the great number of code words and vice versa.

The possibility of construction of priority code with the set lengths of RP subscriber's codes is determined by properties of the synonymous encoding. Therefore it is possible to use the inequality of Kraft for prefix codes [3], which says that it is necessary to execute a condition for prefix code existence in the alphabet of volume D with lengths of codes N_m

$$\sum_{m=1}^{M} D^{-N_m} \leq 1. \tag{11}$$

Using this inequality the condition of admission of correlations of subscribers priorities codes lengths may be formulated at their priority encoding by code with foundation D namely: correlation of lengths of code words N_m may be chosen, $m = 1,...,$ M, which inequality is executed at (3).

CONCLUSION

In this article the alternative approaches to the construction of static RP subscribers codes is considered. However the offered approach allows to serve requests in real time on condition of priorities change in the process of functioning of the system to on-schedule. Therefore the optimum encoding is possible only in case that the optimum rules of changing of priorities codes will be realized in the process of functioning of the system.

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ЗАДАЧИ И МЕТОДЫ СТАТИСТИЧЕСКОГО ОПТИМАЛЬНОГО КОДИРОВАНИЯ ОТНОСИТЕЛЬНЫХ ПРИОРИТЕТОВ ЗАЯВОК НА ОБСЛУЖИВАНИЕ В СИСТЕМЕ ЗАЩИТЫ ИНФОРМАЦИИ ЛОКАЛЬНОЙ ВЫЧИСЛИТЕЛЬНОЙ СЕТИ

Лахно В.А., Петров А.С.

Аннотация. Рассматриваются альтернативные методы оптимального кодирования относительных приоритетов заявок и методы их изменения по расписанию для обеспечения функционирования системы защиты информации в локальной вычислительной сети в реальном времени. Обсуждаются задачи, критерии оптимальности и методы синтеза статистических кодов, неизменяемых во времени или в процессе функционирования системы.

Ключевые слова: системы управления, защита компьютеров, устойчивость, кодирование.