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SYNTHESIS OF A COMPUTER NETWORK FOR CONTROLLING MOVING OBJECTS

Abstract. Today, there are many methods of synthesis of the basic network of the computer control system. But they do not take into account the mobility of control objects. Therefore, the purpose of the article is to develop a method of synthesis of the basic network of the computer control system, which takes into account the mobility of control objects. The method is based on the use of the function of the average loss of messages in the network at the input load and the dynamic resource allocation plan. Regardless of the selected class of the basic network, the developed method assumes: the selection of an appropriate management efficiency assessment function; synthesis of control algorithms for restricting access to the network; synthesis of adaptive routing algorithms that ensure optimal distribution of flows on the short-circuit network. The direction of further research is to take into account the placement of base stations of the computer system.

Keywords: computer system, moving object, core network, optimization, synthesis, cloud computing, fog computing, packet switching, traffic.

Introduction

The basic network of the computer system for managing moving objects should provide users with the following services [1]:

- transmission of information packets from system sensors in real time;
- transfer of packages of control stations and mainframes;
- exchange of information between nodes of the computer system;
- transmission of traffic of local nodes of the computer system;
- access to cloud systems;
- exchange of video images;
- transmission of protected traffic.

To provide the above services, the transit transport mechanism of global computing networks (GOM) is used, which is based on the three lower levels of the OSI network model. In parallel, with the growing popularity of the Internet, the share of services related to the upper levels of the protocol stack is growing: access to hypertext information WEB-nodes, broadcasting of video information, search and delivery of information according to individual orders, etc.

Today, there are many methods of synthesis of the basic network of the computer control system [2–11]. But they do not take into account the mobility of management objects.

Therefore, the purpose of this article is to develop a method of synthesis of the basic network of the computer control system, which takes into account the mobility of control objects.

Research results

A fragment of the structure of a modern basic network of a computer system for managing moving objects, operating in packet switching mode (PC), is presented in Fig. 1, which shows the following blocks: USM - switching or routing devices ; DCE - physical layer protocol support equipment; DTE - network terminal equipment; UNI - "user - network" interface; NNI - "network - network" interface.

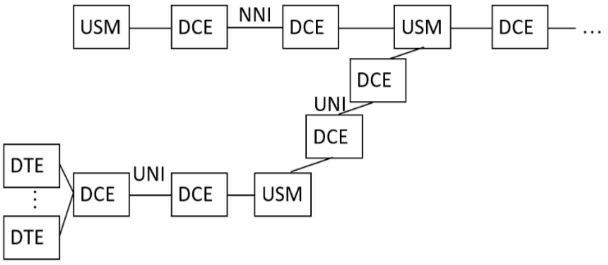

Fig. 1. A fragment of the structure basic network

This option is optimal both from the point of view of the total traffic transmitted by the network per unit of time, and in terms of the cost of network services [2] (other things being equal, a packet-switched network is 2-3 times cheaper than a channel-switched network [3]). However, it is not always possible to build a basic network of a computer system for managing moving objects based on packet switching. Therefore, depending on the allocated communication channels, networks based on allocated channels are also considered. When building all of the listed types of networks, issues related to the improvement of adaptive network management methods, including management of information flows and communication channels, are particularly relevant.

Let's consider the construction of information flow management algorithms that take into account adaptive routing and a number of network constraints (load limitations, buffer memory capacity, and limited bandwidth of communication channels). Let's consider the network as a set of means of communication and switching and network management system. We define the network model as an undirected regular graph $G(V, R)$, where V is the set of nodes of the network, and $R = \left\{ r_{ij} \,\middle|\, i, j \in V \right\}$ is the set of communication lines between them. Let us consider a stationary flow $\Lambda = \{k_{ij}\}$ with a priori - unknown parameters on G. The load coming to the network will be distributed according to given static (P_{st}) and dynamic (P_{dn}) plans, and the routes of the P_{st} plan in any case have priority. The distribution plan of each node i ($i \in V$) is defined by the routing matrix $S_i = \left(p_{il}^j\right)$, $j \in V$, where p_{il}^j is the conditional probability with which a call belonging to the plan P_{dn}, which arrived at the i-th node and is addressed to the j-th node, is directed to the node $l \in V$ on the short circuit $r_{il} \in R$. With a given model of the network management system (M_{sum}), the task of adaptive flow management is the selection of the optimal load distribution of the dynamic plan, which is provided for the given network structure, static plan, network load and functionality, which evaluates the effectiveness of the UE algorithms (F), i.e.

$$F(G, \Lambda, P_{dn}, P_{st}, M_{СУМ}) \xrightarrow[\Lambda, P_{dn}]{} extr .$$

In networks with channel switching, as always, one of the main components of the above functional F is the probability of successful connection establishment, and the management task is the maximum use of the network bandwidth when the input load changes within wide limits. At the same time, it is necessary to avoid unproductive network overloads associated with broadcast messages, repeated calls and unreasonably long routes. These tasks are solved by load limiting algorithms, which limit subscribers' access to the network, and adaptive routing algorithms [4], which limit the choice of outgoing directions.

When considering flows without priorities, it is advisable to use the function of the average loss of messages in the network [5] at the input load Λ and the dynamic distribution plan:

$$W = \sum_{i \in V} \sum_{j \in V} \omega_{ij} = \sum_{i \in V} \sum_{j \in V} \begin{pmatrix} \Lambda_{ij}(\Pi_{dn}, \Pi_{st}) - \\ -(\lambda_{ij} + \lambda_{ji}) \end{pmatrix} \times \times p_{ij}\left(\Lambda_{ij}^{(в)}(\Pi_{dn}, \Pi_{st})\right), \quad (1)$$

where Λ_{ij} is the intensity of the flow arriving according to the given plans to the communication channel r_{ij} from nodes i and j; $\Lambda_{ij}^{(в)}$ is the intensity of the repeated flow on the communication channel r_{ij}; $p_{ij}\left(\Lambda_{ij}^{(в)}(\Pi_{dn}, \Pi_{st})\right)$ is probability of blocking path r_{ij} for flow $\Lambda_{ij}^{(в)}$.

For each of the components of the sum (1), the partial derivatives are equal

$$\frac{\partial \omega_{ij}}{\partial \Lambda_{ij}} = p_{ij} + \Lambda_{ij}^{(tr)} \cdot \frac{\partial p_{ij}}{\partial \Lambda_{ij}^{(в)}} \cdot \frac{\partial \Lambda_{ij}^{(в)}}{\partial \Lambda_{ij}}, \quad (2)$$

where $\Lambda_{ij}^{(tr)} = \Lambda_{ij} - \left(\lambda_{ij} + \lambda_{ji}\right)$

is the intensity of the flow of transit calls on r ij arriving from nodes i and j.

The partial derivatives $\dfrac{\partial p_{ij}}{\partial \Lambda_{ij}^{(в)}}$ of expression (2) under the given conditions have an analytical expression [6]. To estimate their values, an empirical estimate is used, which is calculated on the basis of data on the change in flows Λ_{ij} and $\Lambda_{ij}^{(в)}$ on the previous iteration, i.e.

$$\frac{\partial \Lambda_{ij}^{(в)}}{\partial \Lambda_{ij}}[n] \approx \frac{\Delta \Lambda_{ij}^{(в)}[n-1]}{\Delta \Lambda_{ij}[n-1]}.$$

When routing with priorities, the functional of the average value of the total value of the messages transmitted by the network is considered [7]:

$$\Phi = = \sum_{i \in V} \sum_{j \in V} \left(1 - P_{ij}\left(\Lambda, P_{dn}, P_{st}\right)\right) \int_0^{c_{ij}} L_{ij}(u_{ij}) du_{ij}, \quad (3)$$

where $P_{ij}\left(\Lambda^{(0)}, P_{dn}^{(0)}, P_{st}^{(0)}\right)$

is the probability of message transmission failure by communication channels r ij with limited input load $\Lambda(0)$ and limited plans $P_{dn}^{(0)}$, $P_{st}^{(0)}$; $L_{ij}(u_{ij})$ is the limit function of the value of the messages of the flow passing through the communication channel r ij , when exceeding which $\left(\eta_{ij} > L_{ij}(u_{ij})\right)$ the message transfer requests are accepted by the network for servicing; c_{ij} – limit limit for the flow through the communication channel r_{ij}; u_{ij} is the value of the current flow through the communication channel r_{ij}.

So, in this case, it is necessary to choose such $\Lambda(0)$, $P_{dn}^{(0)}$ and $P_{st}^{(0)}$, at which the maximum of the functional (3) is ensured. At the same time, the synthesis of flow control algorithms can be divided into two stages. At the first stage, it is necessary to synthesize algorithms that ensure a minimum weighted average loss of messages $\Lambda(0)$, i.e

$$\sum_{i \in V} \sum_{j \in V} k(c_{ij}) \cdot \lambda_{ij} \cdot P_{ij}\left(\Lambda^{(0)}, P_{dn}^{(0)}, P_{st}^{(0)}\right) \to \min ,$$

where $k(c_{ij}) = \displaystyle\int_{L_{ij}(c_{ij})}^{\eta_{ij}^{(\max)}} u_{ij} t_{ij}(u_{ij}) du_{ij}$

is the weighting factor determined in accordance with (3) and the average priority rating t_{ij} (u_{ij}).

At the second stage, algorithms are synthesized that provide the maximum total value.

A necessary condition of optimality is the equality of partial derivatives to zero $\dfrac{\partial \Phi}{\partial c_{ij}}$, i.e

$$L_{ij}(c_{ij})\left(1 - P_{ij}\left(\Lambda^{(0)}, P_{dn}^{(0)}, P_{st}^{(0)}\right)\right) - -\frac{\partial P_{ij}\left(\Lambda^{(0)}, P_{dn}^{(0)}, P_{st}^{(0)}\right)}{\partial c_{ij}} \int_0^{c_{ij}} L_{ij}(u_{ij}) du_{ij} = 0$$

or

$$L_{ij}(c_{ij}) = \frac{1}{1 - P_{ij}\left(\Lambda^{(0)}, P_{dn}^{(0)}, P_{st}^{(0)}\right)} - -\frac{\partial P_{ij}\left(\Lambda^{(0)}, P_{dn}^{(0)}, P_{st}^{(0)}\right)}{\partial c_{ij}} \cdot \int_0^{c_{ij}} L_{ij}(u_{ij}) du_{ij}. \quad (4)$$

Since the functional (3) is concave [11], the expression (4) is also a sufficient condition for the optimality of the input load limitation. To implement (4) on $G(V, R)$, you can use iterative procedures that use positive increments of the value c_{ij}. According to the found values of $c_{ij}[n]$ the required value of the threshold L_{ij} is determined for the priorities of messages arriving at the short circuit r_{ij}. When packet switching based on virtual channel switching is used in the network, when the transmission of the message is preceded by the organization of a virtual channel, it is possible to draw a complete analogy with channel switching [12] and therefore expressions (2) – (4) can be applied with some restrictions. When transmitting packets of the same message along different, independently chosen routes (for example, the datagram method), the main requirement for the network is transparency for subscribers. Therefore, message delays in the network must be minimal, and the capacity of the buffer memory is chosen so that, on the one hand, it ensures the intermediate storage of packets transmitted in the network with low delays, and, on the other hand, the probability of overflow is sufficiently small. Algorithms for restricting access to the network and choosing the optimal route are built accordingly.

Conclusions

The method of synthesis of the basic network of the computer control system, which takes into account the mobility of control objects, has been developed. Regardless of the selected class of the basic network, the method assumes: the selection of an appropriate management efficiency evaluation function; synthesis of control algorithms for restricting access to the network; synthesis of adaptive routing algorithms that ensure optimal distribution of flows on the short-circuit network. The direction of further research is taking into account the placement of base stations of the computer system.

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Синтез комп'ютерної мережі для управління рухомими об'єктами

Н. Г. Кучук, А. П. Шиман

Анотація. На сьогодні існує багато методів синтезу базової мережі комп'ютерної системи управління. Але в них не враховується рухомість об'єктів управління Тому метою статті є розробка методу синтезу базової мережі комп'ютерної системи управління, яка враховує рухомість об'єктів управління. Метод базується на використанні функціонала середніх втрат повідомлень у мережі при вхідному навантаженні і динамічному плані розподілу ресурсів. Незалежно від вибраного класу базової мережі, розроблений метод припускає: вибір відповідного функціонала оцінки ефективності управління; синтез керуючих алгоритмів обмеження доступу до мережі; синтез алгоритмів адаптивної маршрутизації, що забезпечують оптимальний розподіл потоків по КЗ мережі. Напрям подальших досліджень – врахування розміщення базових станцій комп'ютерної системи.

Ключові слова: комп'ютерна система, рухомий об'єкт, базова мережа, оптимізація, синтез, хмарні обчислення, туманні обчислення, комутація пакетів, трафік.