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METHOD OF PACKET FRAGMENTATION IN UNSTABLE DATA EXCHANGE IN COMPUTER NETWORKS ON TRANSPORT

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Abstract**:** *Transmission of packets of the maximum length does not in all cases provide the best probability-time characteristics. In such cases, it is customary to use the fragmentation mechanism. This approach is most useful for unstable data exchange in computer networks in transport.*

The purpose of the article is to develop a method for fragmentation of packets with unstable data exchange in computer networks on transport.

The article proposes a criterion for the fragmentation of the original data packets to achieve the maximum possible reduction of the error probability under the given conditions. This criterion is the maximum ratio of the error probability of the original packet to the error probability of the fragmented packet. The dependence of the optimal number of fragments on the length of the information part of the original data packet is shown. A method for calculating the optimal number of fragments with known characteristics of the data transmission channel and fixed sizes of information, service and verification information is presented. It has been proved that the optimal number of fragments increases with an increase in the size of the information part of the packet and with a deterioration in the quality of the communication channel. It is also shown that when using poor quality communication channels for data transmission and/or the need to transmit packets of considerable length, the advantages of fragmentation become more significant. For such conditions, the original packet should be split into smaller fragments.

One of the directions for further research in this area is to determine the criterion for fragmentation of original packets to reduce the average delivery time while increasing the reliability of the data.

INTRODUCTION

Formulation of the problem. In modern data transmission networks, fragmentation is in most cases a necessary measure. Typically, fragmentation occurs when you need to transfer large data over a network with a smaller allowable packet size. During fragmentation, the original packet is divided into fragments of the maximum allowable length for a given network (protocol), since in this case the redundancy introduced by the service bits is minimal [1 – 4].

Analysis of research and publications. It is known from the practice of using data transmission networks that the transmission of packets of the maximum length does not in all cases provide the best probabilistic-temporal characteristics. The transmission quality drops especially significantly in case of unstable data exchange in computer networks [5, 6]. This situation is often found in a network in which sources and receivers of information are mobile, which is especially common in computer networks in transport.

In [7, 8], the case of splitting the original packet into fragments of equal length is considered for the simplest bit-oriented data transmission procedure with acknowledgment for one transmission link. In this case, additional flows of information at the switching nodes are not considered. It is shown that with an arbitrary law of distribution of errors in the communication channel under given conditions, it is possible to achieve a decrease in the average delivery time or increase the reliability of data by choosing the number of fragments. The greatest gain was obtained for poor quality communication channel. In particular, communication channels were considered with the probability of error in a single element $P_o > 10^{-3}$. However, the method for choosing the fragmentation parameters was not considered in these works.

Purpose of the article – to develop a method for fragmentation of packets in case of unstable data exchange in computer networks in transport. As a criterion, it is proposed to minimize the probability of data error as much as possible. The method will allow calculating the optimal number of fragments under the given conditions.

THE MAIN PART

Consider a source package of length N digits. It contains M information, K service and R check digits:

(1) $N = M + K + R$, где $M \geq 1$, $K \geq 1$, $R \geq 0$.

Suppose that the probabilities of correct package delivery $\left(P_{correct}\right)$ and receipts $P_{receipt}$ are equal. Then, for the original packet, the probability of receiving data with an error is determined by the formula

(2) $$P_{error} = P_{undetected} / \left(P_{correct} + P_{undetected}\right),$$

where $P_{undetected}$ – the probability of not detecting errors in the package. With an arbitrary law of distribution of errors in the communication channel:

(3) $$P_{correct} = \left(1 - P_o\right)^N, \; P_{undetected} = \left[1 - \left(1 - P_o\right)^N\right] \cdot 2^{-R},$$

where P_o – one bit distortion probability.

Suppose that during fragmentation, the number of service and check bits in each of the fragments corresponds to their number in the original packet. Suppose the information part of the packet is split into F equal parts ($F \geq 1$).

For variables describing fragments, we introduce the superscript (*fr*). Than [8]:

(4) $$N^{(fr)} = \left]M/F\right[+ 1 + K + R; \quad P_{correct}^{(fr)} = \left(1 - P_o\right)^{N^{(fr)}};$$

(5) $$P_{undetected}^{(fr)} = \left[1 - \left(1 - P_o\right)^{N^{(fr)}}\right] \cdot 2^{-R};$$

(6) $$P_{correct}^{(fr)} = \prod_{i=1}^{F} \frac{P_{correct}^{(fr_i)}}{\left(P_{correct}^{(fr_i)} + P_{undetected}^{(fr_i)}\right)}, \quad i \in \overline{1,F}\,; \quad P_{error}^{(fr)} = 1 - P_{correct}^{(fr)},$$

where]□[nearest integer not less than value □.

Then the ratio of the error probability of the original packet to the error probability of the fragmented packet will have the form:

(7) $$\eta = \frac{P_{error}}{P_{error}^{(fr)}} = \frac{P_{undetected}}{\left(P_{correct} + P_{undetected}\right) \cdot \left(1 - \prod_{i=1}^{F} P_{correct}^{(fr_i)} \Big/ \left(P_{correct}^{(fr_i)} + P_{undetected}^{(fr_i)}\right)\right)}.$$

Let us investigate the dependence of the ratio (7) on the number of fragments (Fig. 1). There are five dependencies when transmitting a packet of length 16K ($M = 131072$ bit). For dependencies 1, 2, 4, 5 such values are chosen: $K = 512$ bit, $R = 256$ bit. In the 3rd dependency $K = 1024$ bit, $R = 512$ bit. The channel reliability is chosen as follows: dependence 1 – $P_0 = 10^{-2}$ (very poor connection); 2, 3 – $P_0 = 10^{-3}$; 4 – $P_0 = 10^{-4}$; 5 – $P_0 = 10^{-5}$.

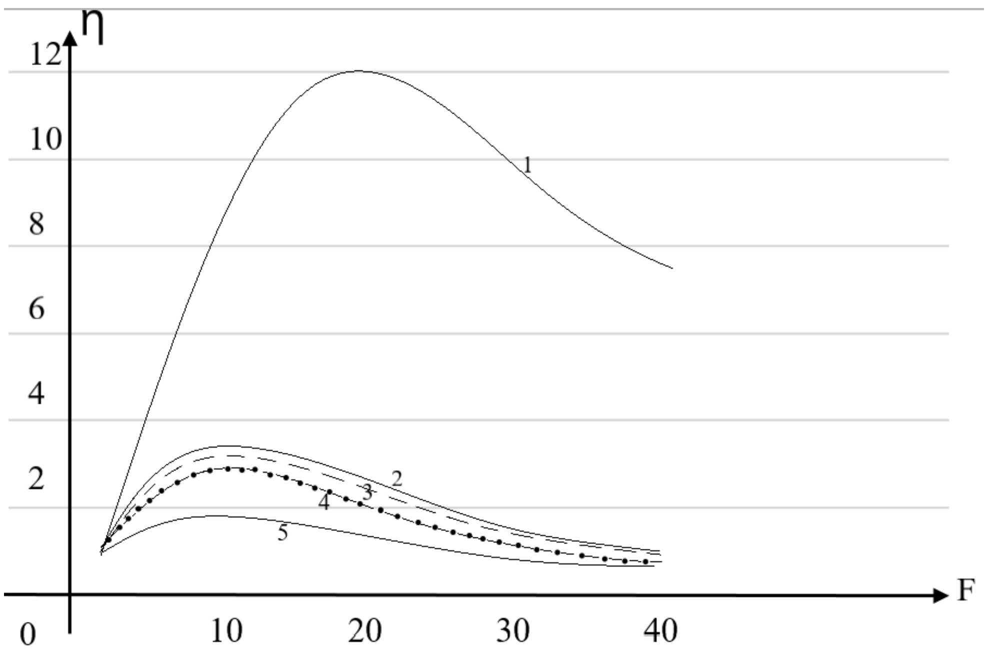

Fig. 1. Dependence of the ratio of the error probability of the original packet to the error probability of a fragmented packet on the number of fragments

The dependencies in Figure 1 show that the ratio η at any parameter values P_0, K and R has a maximum of. This maximum corresponds to the single value of the number of fragments D, which is optimal. An increase in the number of control bits leads to a decrease in this ratio.

Thus, the criterion for fragmentation of the original packets to achieve the maximum possible reduction in the probability of data error without taking into account the change in the average time of their delivery can be written in the form

(8) $$\varphi\left(\eta(F) = \frac{P_{error}}{P_{error}^{(fr)}}(F)\right) \xrightarrow{F} \max, \quad F \ge 1.$$

Finding the optimal number of fragments F_{opt} for given values P_0, *K, M* and *R* can be implemented by performing a sequence of calculations:

$$F := 1;$$

(9) $$\text{while } \eta(F) \leq \eta(F+1) \text{ do } F := F+1;$$

$$F_{opt} = F.$$

For most communication procedures, the parameters *K* and *R* fixed, and P_0 and *M* could change during data exchange. Wherein P_0 depends on the characteristics of the communication channel used, and *M* depends on the parameters of user information flows and / or applications of the sending node.

Calculations carried out in accordance with (9) show that at given values P_0, *K* and *R* dependence $F_{opt}(M)$ step-linear (Fig. 2).

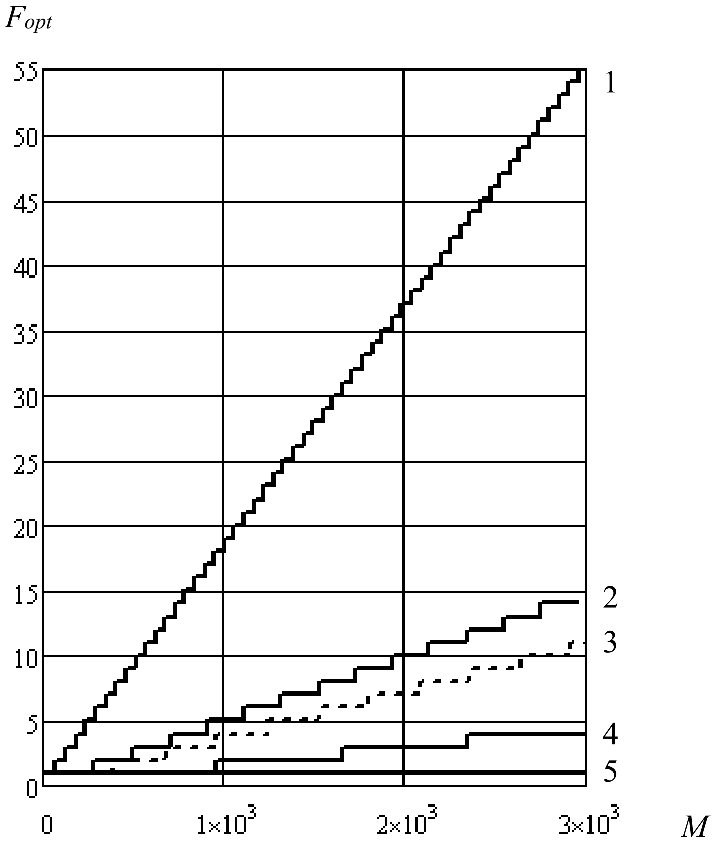

Figure: 2. Dependence of the optimal number of fragments on the length of the information part of the original packets (designations are the same as in Fig. 1)

Then $F_{opt} = \lceil M/\alpha \rceil$, where α – aspect ratio; $\lceil \ \rceil$ – rounding operation to the nearest integer.

From those shown in Fig. 2 dependences it can be seen that the optimal number of fragments increases with an increase in M and with a deterioration in the quality of the communication channel.

A gain in data reliability when splitting source packets into F_{opt} fragments increases with increasing *M* and decreases when using a communication channel of higher quality (Fig. 3).

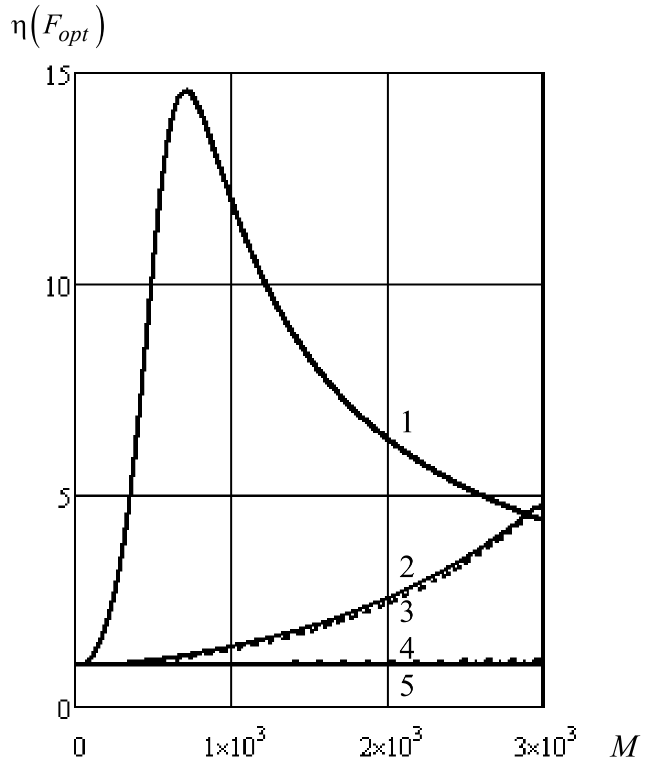

Fig. 3. Fragmentation quality analysis (designations are the same as in Fig. 1)

The length of the information part of the fragments can be defined as

(10) $$M^{(fr)} = \rbrack M/F_{opt} \lbrack$$

and with the given parameters with an increase M asymptotically approaches some limiting value

(11) $$M_{opt}^{(fr)} = \lim_{M \to \infty} \rbrack M/F_{opt} \lbrack .$$

Then for given P_0, K and $R = const$ we get

(12) $$F_{opt} = \left\lceil M / M_{opt}^{(fr)} \right\rceil . \qquad (6)$$

Accordingly, for practical application, the problem of determining the optimal number of fragments under the indicated conditions can be implemented by a sequence of the following actions:

Шаг 1. Determining the approximate value $M_{opt}^{(fr)}$ with a knowingly greater or equal to the maximum possible for a given network (protocol) value M – by formula (10) based on the value F_{opt}, obtained by the algorithm (9).

Шаг 2. Calculation for the current value M the optimal number of fragments by the formula (12).

It should be noted that splitting the original packet into a number of fragments that differs from the optimal one will lead to a decrease in the gain in reliability or even an increase in the probability of an error in data in relation to unfragmented packets. Moreover, the deviation from F_{opt} less critical for a poor quality communication channel (Fig. 1).

CONCLUSION

1. The criterion for fragmentation of source packets in order to achieve the maximum possible decrease in the probability of data error without taking into account changes in the average time of their delivery is the maximum ratio of the error probability of the original packet to the error probability of the fragmented packet.

2. When using poor quality communication channels for data transmission (from $P_0 > 10^{-3}$) and / or the need to transmit packets of considerable length (c $M > 10^4$) the benefits of fragmentation become more significant. For such conditions, the original packet should be split into smaller fragments.

One of the directions for further research in this area is to determine the criterion for fragmentation of source packets to reduce the average delivery time while increasing the reliability of the data.

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МЕТОД ФРАГМЕНТАЦИИ ПАКЕТОВ ПРИ НЕУСТОЙЧИВОМ ОБМЕНЕ ДАННЫМИ В КОМПЬЮТЕРНЫХ СЕТЯХ НА ТРАНСПОРТЕ

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Ключевые слова: *передача данных, фрагментация, вероятность ошибки, критерий фрагментации*

Аннотация: *Передача пакетов максимальной длины не во всех случаях обеспечивает наилучшие вероятностно-временные характеристики. В таких случаях принято использовать механизм фрагментации. Данный подход наиболее полезен при неустойчивом обмене данными в компьютерных сетях на транспорте.*

Цель статьи – разработать метод фрагментации пакетов при неустойчивом обмене данными в компьютерных сетях на транспорте.

В статье предложен критерий фрагментации исходных пакетов данных для достижения максимально возможного при заданных условиях уменьшения вероятности ошибки. Таким критерием является максимум отношения вероятности ошибки исходного пакета к вероятности ошибки фрагментированного пакета. Показана зависимость оптимального числа фрагментов от длины информационной части исходного пакета данных. Приведен способ расчета оптимального числа фрагментов при известных характеристиках канала передачи данных и фиксированных размерах информационной, служебной и проверочной информации. Доказано, что оптимальное количество фрагментов возрастает при увеличении размера информационной части пакета и при ухудшении качества канала связи. Также показано, что при использовании для передачи данных каналов связи плохого качества и/или необходимости передачи пакетов значительной длины преимущества фрагментации становятся более существенны. Для таких условий исходный пакет следует разбивать на фрагменты меньшей длины.

Одним из направлений дальнейших исследований в данной области является определение критерия фрагментации исходных пакетов для уменьшения среднего времени доставки при одновременном повышении достоверности данных.