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FORECASTING OF CORRECTION CODES CHARACTERISTICS TO COUNTERACT NETWORK CHANNEL OVERLOADS

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ABSTRACT

In various data transmission systems, often there are situations when one of the nodes is less productive or more overloaded than the others. Where this node is the only one on the way to data recipients, there is a strong slowdown in data transmission from sources to recipients, and some packets begin to be lost when a certain high load level is reached. The described situations are characterized by a load on the channel without strong variations in intensity and without the threat of a complete shutdown of the system, where the use of coding can have high efficiency. As a method of protection, we chose the reaction method, based on the use of correction codes that are able to restore lost packets due to the occurrence of congestion in the networks. At the same time, due to the variability in the intensity of the data flow in the channel in real systems, in order to reduce the overhead costs when using encoding and generally increase the data transfer rate, it is necessary to choose the data transfer mode (in some cases, encoding will not be more effective than a simple mechanism for re-requesting lost packets) and to determine the code parameters depending on the average probability of packet loss in the channel, which will be sufficient to restore all lost packets. In both cases, it was decided to choose the parameters of the correction code by predicting certain characteristics of the data transmission channel. These characteristics are the average delay between two packets in the channel and the queue load p. After comparing the simulation results with the optimal indicators for a similar system, the high efficiency of the method under consideration was revealed, which suggests that it will provide significant resistance to moderate loads in the channel.

Keywords: *Noise-Resistant Coding, Information Interaction, Overload Protection, Telecommunications Systems and Networks.*

1. INTRODUCTION

Due to the total spreading and to a lot of types of destructive effects (overloads) on the channel, it is proposed to focus on a certain, narrower category of such overloads: on the impact of moderate-level interference (planned channel load without threats to complete system shutdown) on a system with a limited throughput ("bottleneck"), where the use of the encoding has a certain efficiency (high packet loss probability in the system leads to a sharp decrease in efficiency, therefore, the lower and the upper limits of the applicability of encoding to improve the data transmission process [1]) should be taken into account (Figure 1).

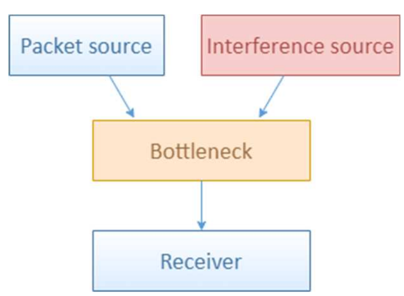

Figure 1: Model of the system under influence of channel overload in question

This problem can often be solved by redirecting of traffic through other nodes (for example, using load balancers as in the work [2]), but the above model is relevant in cases when this is the only node on the way to data receivers. As an example of such systems can be an enterprise, where, due to the requirements for the security of data and

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internal systems, the maximum possible restriction of input nodes to the system is made. The relevance of the problem is also indicated by the presence of a large number of studies on the occurrence of overloads in a bottleneck, including those concerning the development of algorithms for counteracting of overloads [3].

At the same time, it is important to note that the above mentioned loads can be both malicious (DDoS attacks of insufficient power) and not malicious (in case of a serious increase of the number of requests to a certain service by legitimate users).

First of all, it is necessary to carry out an extensive study of the suitability of using of the method proposed in the article, therefore it is planned to simulate the process of operation of such a method with the selection of various system parameters and subsequent comparison of the results obtained with the optimal values for the developed system.

2. THEORETICAL BASIS

Protection against various destructive influences can be divided into two main protection classes: preventive and reactive ones. The preventive one relies on the forecasting of impacts and preparation for their mitigation even before the impact begins, while the reactive one works immediately during and/or after the impact, protecting the target from the resource depletion. This classification is used in a number of works investigating the counteraction to various influences over time, that's why it was taken as the basis in this work [4].

Preventive protection methods are an extremely important element in counteracting of overloads but they have a high cost of installation and support, and it is also possible that the preventive protection will not work. In these cases, a reactive protection is an attractive option both as an addition to the preventive protection and as an independent protection method. The reactive protection also uses a traffic that has already entered the system. Such a protection can be disabled when the system is not affected, which makes it extremely attractive in terms of installation and maintenance costs. The disadvantage of the reactive protection system is that it needs time to react to the impact, which creates a small, but still quite significant delay between the start of the impact and the start of the reactive protection [5].

For the case of the protection method considered in the article, it is first of all worth turning to reactive protection measures, since coding supposes the choice of certain code parameters, which requires the information on the system state [6].

The system implies a "sender-receiver" architecture, when a one-way connection is established between the sender and the recipient, which allows the transmission of loss-sensitive data in an encoded format in case of poor communication quality between the sender and the recipient, which causes an increase in the probability of packet loss in the channel. Since the level of loss can change over time, it is proposed to use the prediction of the correction code parameters, which will allow adjusting the required level of packet recovery to potential conditions (losses) in the channel in the near future. For this, we need to formulate key prediction parameters, select a corrective code and set boundaries when the coding will actually be effective, which will be done in this work.

3. METHODOLOGY

To select the code parameters that will make the coding application effective, it will not be possible to rely only on the current system parameters, since in this case the coding will "lag behind" the real losses. In other words, by the time when redundant packets are added to the data subject to the characteristics of the network (packet losses, latencies etc.), another correction capacity will be required, which means that the packets sent will already be irretrievably lost.

If there are losses in the system and the use of the repeat request mechanism is no longer so effective, then the simplest option in this situation will be to select such code parameters that will guarantee the absence of losses at any time. However, it is important to note that, although in case of satisfaction of such conditions it will indeed be possible to achieve no losses by using the coding, but such a method will give a real advantage only at high loss values, and in case of small losses, the use of iterative queries will often be more effective. This is due to the fact that though the use of the acknowledgment mechanism slows down data transmission and increases the delay because of iterative queries when losses occur, but with very small (less than 0.1%) loss values and a small (less than 50 ms) transmission time to the receiver and

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back, all newly requested packets will finally reach the receiving side [7]. With low losses, a large redundancy will significantly reduce the intensity of data transmission, which may be more significant than the reducing of the intensity of data transmission when using repeat request mechanisms. In addition, it is not possible to assume that the losses on a certain time interval will not exceed a predetermined value in the case of a dynamic process of destructive influence, when its intensity changes during one connection/session. In this regard, it is proposed to use the forecasting when selecting code parameters. Depending on certain conditions in the channel it will allow:

1. To select such code parameters that will allow to minimize overhead costs and achieve a maximum code speed, thus solving two problems at the same time: large and inefficient redundancy with small losses, as well as the requirement to forecast the upper limit of losses. At the same time, it is important to note that it is possible to forecast a dynamic process of the destructive impact as well as a static one in order to obtain correct code parameters. The case of a static forecast is also a priority as despite the fact that the stream itself will be static (the intensity of data transmission will not change), the connection often lasts for a short time, and during each connection, the load of the stream may change. In this case, it makes sense to analyze the primary losses in the channel and, in accordance with this, to select certain code parameters for the entire session period;
2. To choose between the repeat request mechanism and encoding, subject to the level of loss. In case of rather low loss values, encoding will be less efficient, even taking into account the fact that the costs for the encoding and decoding are low. In this case, it makes sense to disable encoding in principle and to use the handshake mechanism. This will be one of the options for implementing of a hybrid system with repeat requests and an error correction coding mechanism.

In view of the foregoing, the methodology of the study to determine the characteristics of the corrective code is as follows: choice of the goal, method and indicators of forecasting. As a goal, it is proposed to use short-term prediction of channel parameters (throughput, packet delays in queues). The most adequate forecasting method is polynomial regression analysis. The parameters that will be predicted are ρ (queue load) and the average probability of packet loss over a certain interval. Details of the rationale for each step are provided below.

3.1 Selection of a purpose of the forecasting

By the purpose of the forecasting, we will mean the kinds of the processes forecast in the developed method of counteracting destructive influences on the channel. It is possible to make a short-term reactive forecasting, when, subject to the packets input into the system, there is made a forecast of the state of the following packets or other parameters, such as the average packet loss probability on a certain interval, the intensity of the data transmission or the queue workload. A short-term forecasting means a small number of values, between which there is a statistical dependence. It is also possible to make a long-term forecasting, when a preventive analysis of various parameters is performed and a forecast for a certain period is made on their basis. For example, it is possible to study the system load during a week and for each certain day or hour to give a forecast about the possible workload of the end device. In addition, it is possible to forecast quarterly as it was made in the work [8].

In this article, it is proposed to use a reactive short-term forecasting of channel parameters based on information on lost or successfully received packets due to the fact that this option will allow to select instantly code parameters and to apply in future the coding to prevent losses, regardless of the nature or type of the impact.

3.2 Methods for the forecasting of the load level changes in the channel

Since there are many methods for the forecasting of changes in the load level in the channel, it is necessary to consider various methods and to select the most appropriate one. It should be noted that there are two main categories of forecasting methods: qualitative and quantitative ones. Qualitative methods are based on the opinion of experts and are essentially subjective, they are usually used in the absence of accumulated data on the model [9]. They are more suitable for medium- and long-term forecasts, and they are not suitable for the forecasting of the characteristics of the traffic subject to a strong fluctuation on a short-term interval. In this regard, quantitative methods will be considered further in the work.

One of the simplest methods of the forecasting of the parameters succeeding in a range is a linear

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dependence when it is assumed that the next value will depend on the previous one. In the conditions of working with M/M/1/K systems, this can be a forecast of the fact whether the next packet in the queue will be lost or it will be delivered successfully. If the packet sent by the source has successfully reached the end device with the queue, it is assumed that the next packet will also be delivered successfully. If the last packet is lost, it is assumed that the next packet will be lost.

To select the correct parameters for the code, knowledge only about the last packet is insufficient, so the information is accumulated on a certain (predetermined) number of the last packets and either the average loss probability on this interval is determined by them, or an attempt to forecast the parameter p (queue workload) is made, with which it is already possible to select code parameters. The specific parameters of the code depend on the selected encoding option.

The moving average method is an empirical method for forecasting and smoothing time series. When using such a method with a large value of the forecasting depth, the reaction to changes of the values will be insufficient so that the curve of the series change quickly its direction, and with a small value of the forecasting depth, the forecasting error will be high. However, this method suits well for the forecasting of a parameter that does not require a quick reaction to its change and can be used as a method that complements or guides another forecasting method.

The principle of polynomial regression analysis with given points is to select such a function that approximates the set of these points as accurately as possible. In the framework of the forecasting of the code parameters, this means a selection of a number of points generalized by one specific parameter of the system and a construction of an appropriate regression function, which can then be used to forecast the next parameter. At the same time, for a successful forecasting it is necessary not only to select an appropriate parameter of the system, but also to select a correct degree of the polynomial, otherwise the forecast function may have excessive fluctuations which will lead to extremely inaccurate results.

The results of polynomial regression analysis often lose the accuracy with an increase of the remoteness of the forecast point from the last known value, but they allow determining rather accurately the trend of the direction of a number of points, while knowledge of previous values in the system is required. For the model proposed, such a forecasting option is valid since it is possible to remember the information on any system parameters that are known to the forecast device. In addition, for the forecasting it is proposed to make specifically a short-term reactive forecasting, when it is necessary to determine exactly the trend of the curve of a certain parameter.

The development of information technologies has stirred the interest in the forecasting by various intellectual methods including the use of neural networks. This method is preferable in systems where the traffic that causes overloads will be static or will not have an unpredictable character - in this case one can perform the training in advance and then use the already configured model only for the forecasting without the training. Otherwise the training will be needed during the data transfer based on the traffic that is currently entering the system. At the same time, the packet processing system is required to have a reserve of the computing power, with which the use of neural network training will not give an excessive load to the system, and the session is long. If the session is short, then the use of neural networks can only harm since at the beginning of the training, neural networks have an extremely high rate of erroneous results.

Based on the results of the presented analysis, it is proposed to use a polynomial regression analysis for forecasting of the system parameters, since it allows to forecast trends in a short period of time with a high accuracy.

3.3 Selection of forecasting parameters

It is important to use the parameters that will allow to select correct lengths of the information and code sequences of the code. In other words, these parameters should be correlated with the code parameters.

It is proposed to use one of two parameters: \rho (queue workload) or the average packet loss probability on a certain interval. It is important to note that both parameters are related since the increase of the queue workload eventually leads to losses in case of its overflow, while a stronger workload on the queue correlates with an increase of the number of losses in the network. The difference consists in the complexity of the forecasting since an accurate forecast of the queue workload could make it possible to select the correct code parameters in advance and, as the result, to avoid undesirable losses, but the forecasting of the queue workload is a more difficult task due to the inability to find out immediately the queue workload parameters in a "bottleneck".

Forecasting of the average probability is the most evident option, since the choice of code parameters directly depends primarily on the number of packets lost over a certain period.

For this purpose it will be necessary to storage a certain number of the last packets into the array to calculate the average loss probability on this interval. The length of such an array of packets is called the forecasting depth which is selected based on the size of the queue window. In addition, for the forecasting it is required to storage the last values of the parameter, so the average loss probability is also stored into the array. After that, this array can be used to get the estimated value of the loss probability, which should be determined only on the next interval.

It is proposed to obtain the forecast parameter using a polynomial regression method: a fixed value of the degree of the polynomial will be selected, and then a polynomial will be compiled for each data set with a certain forecasting depth, with the help of which the next parameter in the range will be forecast.

The queue workload parameter p is connected with the intensity of the entering of data λ into the queue with the formula $\rho = \frac{\lambda}{\mu}$, at the same time, μ (packet service intensity) in the framework of this work is a fixed value and, to simplify the model, it is specified to be equal to 1. Therefore, the given ratio can be simplified to $\rho \approx \lambda$. In this regard, supposing that it is possible to forecast the queue workload with a sufficient accuracy, this also gives knowledge about the intensity of packets entering the queue, which in the case of the developed model is the main input parameter.

This allows to perform in advance a loss analysis on various fixed values of data transmission intensity after collecting statistics on the lost packets, and then after selecting the code parameters corresponding to each intensity value.

To forecast the queue workload, the information on the packet loss will be insufficient, so it is proposed to use the average delay value between two packets. In this case, the forecasting will be made with the use of a greater forecasting depth than in the previous point, since the change of the intensity of the incoming stream does not occur so often and is not so critical as queue overflow and, accordingly, packet losses. It is supposed to use this forecast as a complement to the previous one in order to prepare the necessary code parameters for a possible occurrence of losses.

3.4 Structure of disrupting effects counteraction method with the use of the forecasting of correction codes parameters

The calculation of the code parameters based on the forecast average loss probability is calculated with the following formula (1):

$$t = \frac{n-k}{2}, \quad (1)$$

where t is a correction capacity of the code, k is a number of information packets, n is a length of the code sequence.

Parameter t shows the number of packets that need to be restored. It can be obtained from the average loss probability of on a given interval since this parameter is forecast. Parameter n is selected depending on various conditions, including the maximum queue length. After that, k may be obtained, thus forecasting the code parameters. If a non-integral number is obtained, we can either change n or round it down k (at the same time, the code speed will decrease).

For different values of the intensity of data entry into the queue λ, correct code parameterscan be got for each of the values λ. For this purpose, a model developed in [10] was used. The search for optimal lengths of information (K) and code (N) sequences of network code when modeling a queuing system M/M/1/K is performed according to the following criteria: maximization of the code speed and minimization of the length of the code sequence, provided that the packet loss probability is equal to zero.

In the Figure 2 there is a block diagram of the proposed reactive method for counteracting destructive influences in the channel. The forecasting method is based on the M/M/1/K queuing model, the selection of which is determined by the most suitable model parameters for the operation: an exponential distribution is used to calculate the packet processing time and to generate packets, one queuing device is used to process packets, and it is possible to use a variable queue length. The RED queue overload control algorithm is also added to the model to simulate real packet processing systems. This system will allow to model packet transmission process between the source and the receiver, which is necessary to study the effectiveness of the method proposed.

The main component of the method is the assessment of the correction capacity of the code (t1, t2) according to the forecast parameters of the queuing system model and the selection of the parameters (*n, k*) of the code taking into account the greatest forecast correction capacity and their use as a result of the forecasting.

To use the described method, it is necessary to forecast the code parameters. The code parameters are selected based on two indicators: the average packet loss probability on a certain interval and the queue workload *p*. These indicators are forecast based on the delay of packets and the information whether the packet is lost or not.

The next step is to select the code parameters according to the indicators forecast. To select the code parameters based on the queue workload, first data was obtained for different values of *p* (with a static input traffic) [10], [11], and then a matrix was constructed based on the results obtained, according to which it is possible to select code parameters for various queue workload values. After the obtaining of two values of the code parameters in a certain moment of time, the worst case is selected from these two values and used as a forecast result, that is, the code with the biggest correction capacity is selected.

4. RESULTS

Having completed the construction of the simulation model with the implemented overload counteraction method, one can start checking the operability of the proposed prototype. For this purpose, it is necessary to make conditions under which the results of forecasting of the developed method will be considered successful.

For this purpose, it is planned to consider the correctness of selection of the code parameters during the forecasting compared to the optimal code parameters. At the same time, exceeding the forecast redundancy parameter is acceptable since in this case the code speed will only be reduced, and values below the optimal ones are extremely undesirable since in this case the packet will not be subject to the recovery by encoding and it will be necessary to request it again. In addition, it is necessary to assess whether such a method gives an advantage in general, and therefore it is necessary to compare the number of packets requested again by this method and in the absence of the coding in principle.

It is important to note that for the testing in conditions most closely resembling the real ones, the traffic overloading the channel will not be static but pulsed and modifying in time. This will be clearly visible on the queue workload forecast graphs.

There were taken parameters with which there were no overloads in the queue of the queuing device ("bottleneck" of the network to which the impact is directed), when it is impossible to restore all the packets. Before the obtaining of the forecast of the code parameters, graphs of the forecast of the queue workload *p* (Figure 3) and the average packet loss probability he in a shorter period (Figure 4) were obtained.

Figure 3 shows that the actual queue workload is a simplified model of changing loads in the channel over time. The system with the distribution of incoming packets is subordinate to the Poisson distribution law (due to the lack of a large amount of information on the processes in telecommunications systems and their randomness), and therefore allows to simulate real changes of the intensity in a channel with varying load parameters. It is important to note that if the process is well known (that is, the purpose of the study is not the traffic of a format subordinate to the general rules of the M/M/1 model [12], [13]), then other types of distribution can be used.

Then graphs of the code parameter forecasts for two parameters and a general worst-case graph for shorter intervals were obtained (Figure 5, Figure 6).

5. DISCUSSION

There is obtained a graph of comparison of packets lost that require a repeat request using the method described in the article and those without the use of the encoding (Figure 7).

These graphs show that the forecasts have a quite high accuracy, while the use of the algorithm allowed to reduce the number of packets with a repeat request by 94.22%, and the main part of the packets missed by the algorithm is due to a sharp increase of the intensity of the packet transmission in the channel.

At the same time, an increase of the load on the channel leads to a sharp decrease of the forecasting accuracy and of the efficiency of packet recovery (Figure 8). In the case of an increase of the load on the channel from 1.1 to 1.2, the reduction of the number of the packets with a repeat request and with the developed algorithm decreased to 82.35%.

The accuracy of the obtained results is comparable to similar works on predicting DDoS attacks [15]. However, it should be noted that other key parameters and models for forecasting were used in this work, which is also of interest for further research.

The results obtained are relevant for networks with a low level of delays, since the polynomial method makes it possible to make fairly accurate predictions only in a very short interval. If delays are increased in the channel, then the response to changes in the transmission parameters in the channel (probability of packet loss, average delay between packets) will be reduced, which requires more "deep" prediction (prediction for longer periods of time). A review of such studies as [14] allows concluding that it is for such cases with increased delay that the use of a neural network approach is promising.

6. CONCLUSION

It was found out that the developed forecasting protection method efficiency is quite high, while being lower in case of overloads on the bottleneck. This is due to the fact that because of the exponential nature of the packet generation, the packet transmission rate occasionally increases sharply with the same input intensity. In this regard, the code parameters forecasts both by the queue workload and by the average packet loss probability are slow to respond to sharp impulse-like variations in packet transmission intensity, which causes packet losses.

At the same time, based on the graphs obtained during the experiment, it is possible to draw conclusions about the limits of applicability of the method developed. With the current forecast settings, even eith the encoding, the system will not be able to restore the packets if there are more than 50% of losses in a short period (about 40 packets), and the average load on bottleneck exceeds 1.1. It is important to note that although in this case the algorithm will use a repeat request mechanism, it will still be possible to restore packets but in this case the delays for the receiving of the packet will greatly increase. In this case the lower limit of the queue utilization is less than 0.8 when rare individual losses occur that could be fixed by automatic repeat request without an additional code redundancy.

Functional test of the algorithm showed that the algorithm efficiency drops when the application limits are really expanded. It should also be noted that the use of the polynomial method in real systems may not give such good results in packet recovery, since when communicating between devices that are sufficiently distant from each other, there is almost always a significant delay for the algorithm. However, the study within the framework of the simulation shows a high potential efficiency of the algorithm, and the evaluation of other studies, such as [14] and [15], suggests that when using forecasting methods based on the neural network approach, significant efficiency can be achieved even with increased network delays.

The results show that the method proposed can be effective for protection from moderate-level disruptive effects on bottlenecked rate-limited systems when the channel workload is in proposed limits. Further research in the direction of improving of the forecasting method will potentially allow to expand the applicability limit, allowable network latency and to increase the accuracy of the forecasting and, as the result, the percentage of packets restored within these limits.

7. ACKNOWLEDGMENT

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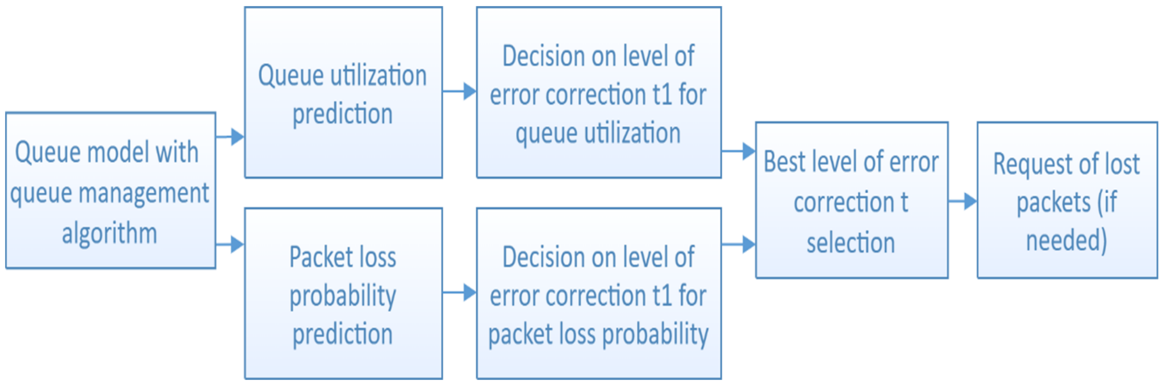

Figure 2: Structure of the proposed counteraction method of disrupting effects on the channel

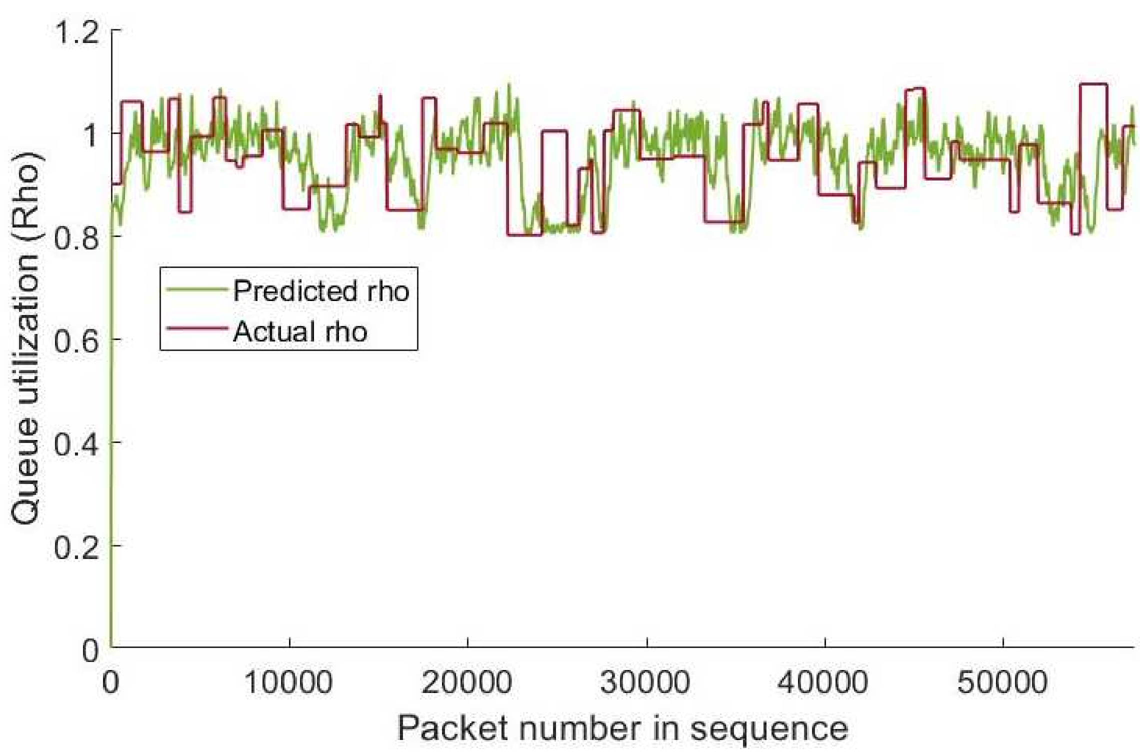

Figure 3: Queue workload forecast for moderate load levels

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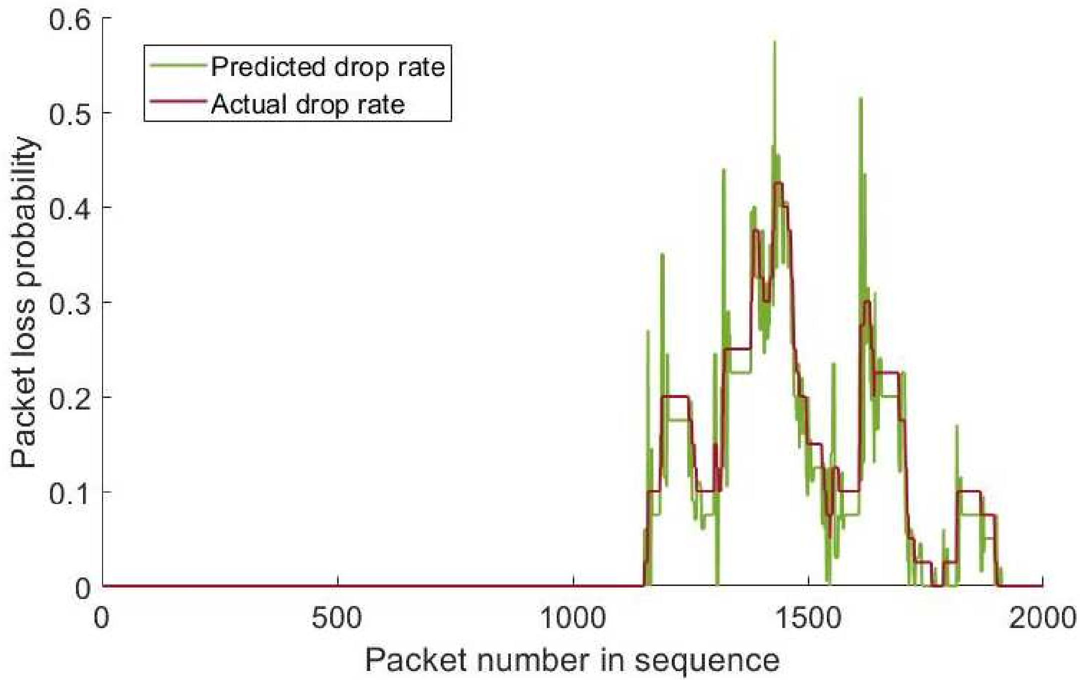

Figure 4: Forecast of the average packet loss probability for a moderate load levelover a short period

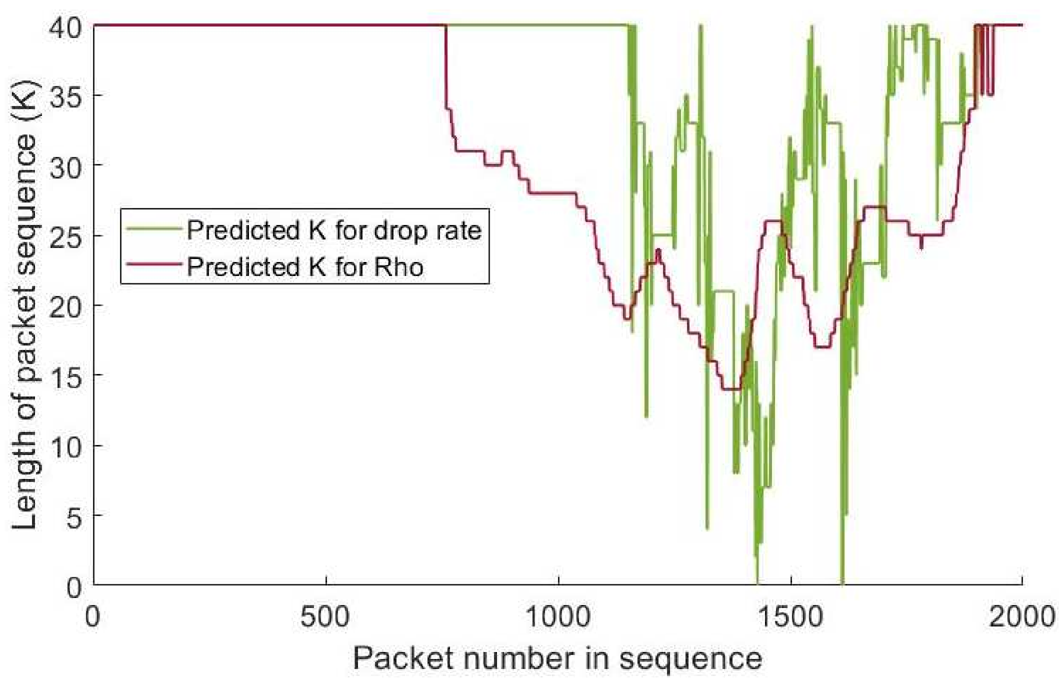

Figure 5: Forecast of code parameters based on two indicators for a moderate load level on a short interval

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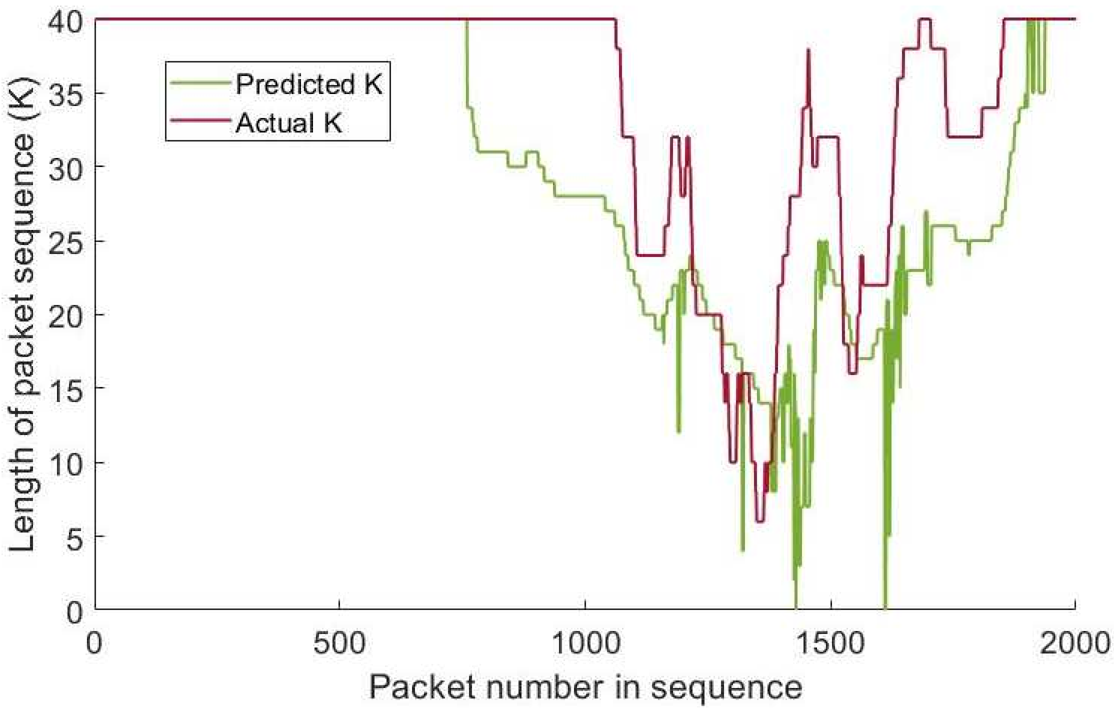

Figure 6: Resulting forecast of the code parameters for a moderate load level on a short interval

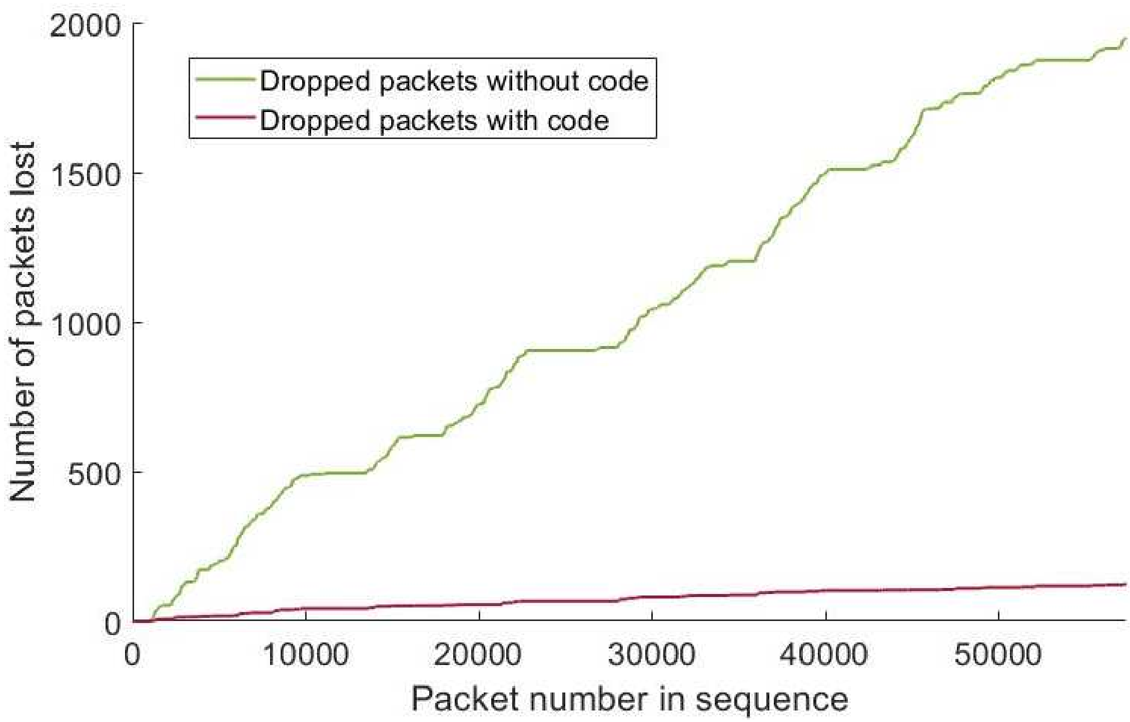

Figure 7: Lost packets count comparison with and without algorithm for a moderate load levels

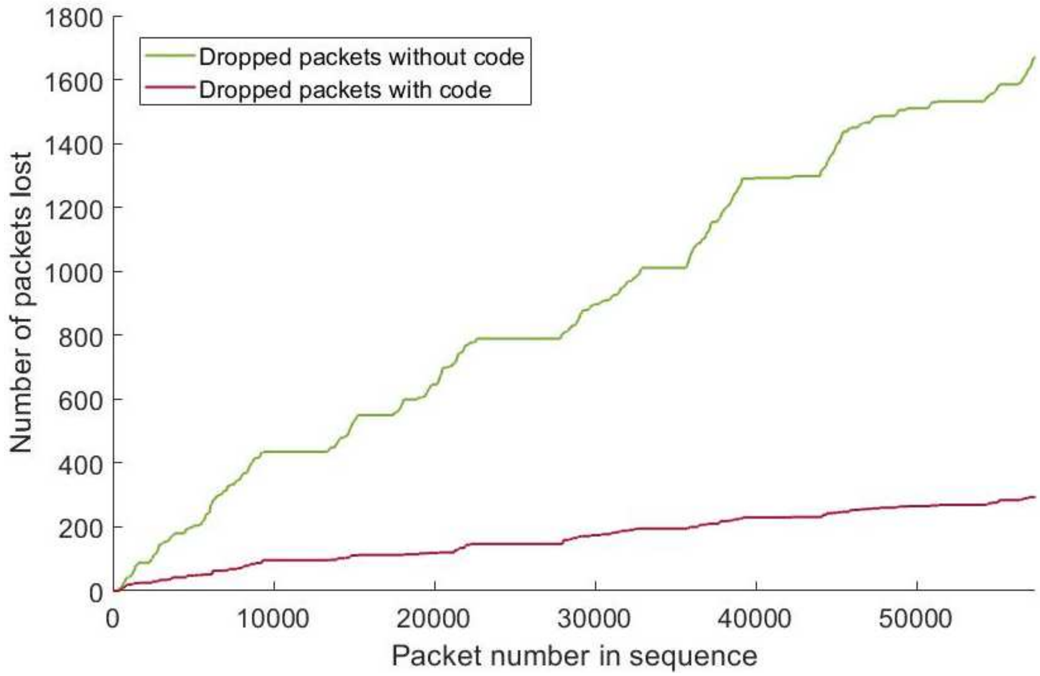

Figure 8: Lost packets count comparison with and without algorithm for an increased load levelsload