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Chang Shu, *Candidate of Sci (techn.).* Northwest University of Politics And Law, People Republic of China

SHAPING OF TRAFFIC PARAMETERS AND ELIMINATION OF OVERLOAD IN AERONAUTICAL TELECOMMUNICATION NETWORKS

Чанг Шу. Формування параметрів трафіку і усунення перевантаження в авіаційних телекомунікаційних мережах. Розглянуті задачі забезпечення якості сервісу в мережах авіаційного електрозв'язку. Розроблений метод управління мережею на основі розділеного оцінювання і управління як єдиний підхід для адаптивних систем реального часу. Завдяки урахуванню і компенсації випадкових затримок управляючої інформації знижується негативний вплив цих затримок. Розроблений метод багатошвидкісного адаптивного формування трафіку із застосуванням дірявого і маркерного відер змінного об'єму.

Ключові слова: АВІАЦІЙНА ТЕЛЕКОМУНІКАЦІЙНА МЕРЕЖА, ЯКІСТЬ ОБСЛУГОВУВАННЯ, **ПАРАМЕТР ТРАФІКУ, ПЕРЕВАНТАЖЕННЯ,** АДАПТИВНА СИСТЕМА РЕАЛЬНОГО ЧАСУ

Чанг Шу. Формирование параметров движения и устранение перегрузки в авиационных телекоммуникационных сетях. Рассмотрены задачи обеспечения качества сервиса в сетях авиационной электросвязи. Разработан метод управления сетью на основе разделенного оценивания и управления как единый подход для адаптивных систем реального времени. Благодаря учету и компенсации случайных задержек управляющей информации снижается отрицательное влияние этих задержек. Разработан метод многоскоростного адаптивного формирования трафика с применением дырявого и маркерного ведер переменного объема.

Ключевые слова: АВИАЦИОННАЯ ТЕЛЕКОММУНИКАЦИОННАЯ СЕТЬ, КАЧЕСТВО ОБСЛУЖИВАНИЯ, ПАРАМЕТР ТРАФФИКА, ПЕРЕГРУЗКА, АДАПТИВНАЯ СИСТЕМА РЕАЛЬНОГО ВРЕМЕНИ

Chang Shu. Shaping of traffic parameters and elimination of overload in aeronautical telecommunication networks. The problems of quality of service in the aeronautical telecommunication networks are researched. The method of control of networks based on partitioned estimation and control as unified framework for adaptive real-time systems is developed. Considering of random delays of control data and compensating of delays due to prediction of traffic parameters in advance we decrease negative impact of these delays. The method of multi-speed adaptive shaping of traffic with the leaky and token buckets of variable volume is developed.

Key words: AERONAUTICAL TELECOMMUNICATION NETWORKS, QUALITY OF SERVICE, OVERLOAD, TRAFFIC PARAMETERS, ADAPTIVE REAL-TIME SYSTEM

As it had been shown in [1], aeronautical telecommunication network (ATN) has some specific features. Firstly, it is the system of critical application, which is characterized by great spread in values of necessary calculating resources for optimum and extreme cases. All telecommunication services must be represented in real time-scale under any conditions of implementation. Secondly, it is heterogeneous system having huge number of network and terminal equipment with large range of technical parameters, application interfaces and protocols. It’s clear that capacity, quality of service (QoS), reliability and other characteristics of network in general are limited by corresponding characteristics of the most poor chain link. Thirdly, the requirements to QoS, especially to reliability of data transfer, have to be very high since aviation safety depends from unbreakable work of communications directly.

Besides, ATN as any complex and distributed system is system with delayed response. The sources of delays are fundamental limitations on speed of propagation of signals through any physical media and communication and processing nodes, such as switches, routers etc. We may consider these limitations on the stages of projecting and technical exploitation of networks.

Another serious sources of delays, losses and forced retransmissions of data are overloads and congestions of critical parts of network. The most efficient way of loss control is continuous analysis and optimal control of network functioning including routing and redirection of data flows.

A number of different control mechanisms have been proposed to solve these problems. Algorithms of traffic policing and shaping such as leaky and token buckets are ones of the methods widely used in the network access control field and they can dynamically allocate bandwidth and efficiently minimize packet losses. Additionally, different control strategies were proposed to manage traffic flow into the backbone network. The results showed that the feedback control laws can improve network performance by improving throughput, reducing packet losses, and relaxing congestion. On the other hand, in [2], it was observed that the system performance was highly degraded in the presence of feedback delay (arising from communications). Due to the time delay, what we capture in real time is the lagged or delayed traffic information. Control based on delayed information leads to excessive degradation of network performance. Thus, in practice, its impact cannot be ignored and must be taken into consideration and compensated for. This paper is dedicated to dissolving of mentioned problems.

Traffic prediction methods have been widely used in network management. By use of prediction techniques, that is, forecasting the future behavior of the traffic, one can effectively prevent traffic jams, traffic congestion, and network crashes. Inspired by these ideas, we have applied prediction techniques [3, 4] to solve the problems encountered in [2].

For this purpose, we propose a real-time feedback control mechanism based on the predicted state and traffic. The traffic and state information are predicted for different values of prediction times based on their past history (the traffic history measured online). An accurate prediction for the future traffic and state (short-term prediction) is able to provide better control compensating for time delay. Thus the impact of time delay can be minimized and the system performance improved.

In this work an online predictor based on the principle of the least mean square error (LMSE) is developed. It is one of the simplest methods. It was noted in [5], that LMSE can achieve better accuracy compared to those complex long-memory predictors for online measurements. Without the requirement of complex computation, it can be implemented at a high speed. As a result of traffic prediction, the system performance degradation due to delay is reduced by use of proper control actions. According to our results, it is possible to optimize the system performance and minimize the cost function by implementing the new method.

In order to understand and solve the performance-related problems in computer communication network, it is critical to build a dynamic model of the information flow through the system (Fig.1). Further, the basic statistical properties of measured trace data must be known.

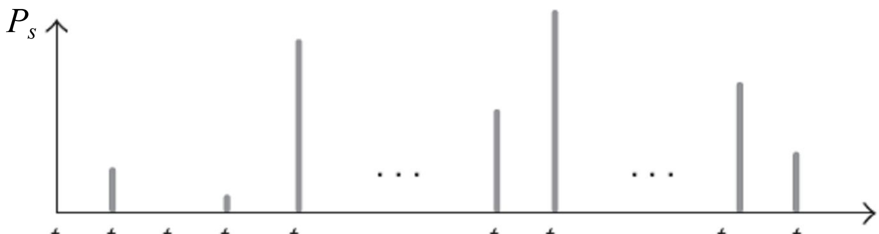

Fig. 1. General model of network traffic. P_s – packet size (bytes).

Traditional characterization of the Internet traffic is based on the Poisson process (which exhibits short-range dependence), Bernoulli process, or more generally doubly stochastic Poisson process (DSPP).

A recent study [5] shows that network traffic has self-similarity characteristics and long-range dependence. Self-similarity means that a certain property of traffic behavior is preserved over space and/or time scales, and long-range dependence is said to exhibit long-term correlations which decay at rates slower than exponential ones. On the other hand, the correlation functions of traditional traffic models decay exponentially or faster. In this paper, a general model is constructed to simulate the incoming traffic illustrated in Fig. 2, which is similar to those in [7].

To simulate a network, we construct a mathematical model comprised of N individual users (traffic streams), served by N corresponding, all of which are coupled to a multiplexor connected to an outgoing link having (bandwidth) capacity C.

Each token bucket implements its algorithm to police the arriving packet. The nonconforming traffic streams are dropped while all the conforming traffic are multiplexed and queued up for entering the multiplexor. As a matter of fact, not all conforming traffic from token buckets will be accepted because of the size limitation of the multiplexor (buffer size Q) and the link capacity (speed) of the accessing node. If the sum of these traffics exceeds the multiplexor size, some part of the conforming traffic maybe dropped. The discarded traffic is defined as the traffic loss at the multiplexor $L(t_k)$.

In general, the traffic loss at the token buckets during the k_{th} time interval is given by

$$L_T(t_k)=\sum_{i=1}^{N} r_i(t_k)=\sum_{i=1}^{N}\left[V_i(t_k)-g_i(t_k)\right],$$

where $V(t_k)$ – packet size of the arriving traffic; $r(t_k)$ – conforming traffic; $g(t_k)$ – non-conforming traffic, while the multiplexor loss during the same time interval is given by

$$L_M(t_k)=\sum_{i=1}^{N} g_i(t_k)-\sum_{i=1}^{N} g_i(t_k)\wedge\left[Q-\left(\left[q(t_k)-C*\tau\right]\vee 0\right)\right]$$

In addition to these losses, it is also important to include a penalty for the waiting time or time spent on the queue before being served. For simplicity we assume that it is unambiguous function of queue length.

Adding all these, we obtain the cost functional. Since the incoming source (or user demand) is a random process, we must compute the average cost as being the expected value of the sum of all the costs described above. This is given by

$$J(u)=E\left\{\sum_{k=0}^{K}\alpha(t_k)L_M(t_k)+\sum_{k=0}^{K}\beta(t_k)L_T(t_k)+\sum_{k=0}^{K}\gamma(t_k)q(t_k)\right\}, \qquad (1)$$

where u is the control law which determines the state of the system and hence the individual losses and finally the total cost. The functions α, β, γ represent the weights or relative importance given to each of the three distinct losses.

Since the exact stochastic characterization of our traffic is not available or is unknown, the Monte Carlo method is employed to compute the expected values of the performance measures. For applying the Monte Carlo technique [8], we let N_s denote the number of samples used and let $\Omega = \{w_j,\ j = 1,2,3,\ldots,N_s\}$ denote the elementary events or sample paths with finite cardinality N_s. The objective functional (1) is then given by

$$J(u)\cong\frac{1}{N_s}\sum_{j=1}^{N_s}\left\{\sum_{k=0}^{K}\alpha(t_k)L_M(t_k,\omega_j)+\sum_{k=0}^{K}\beta(t_k)L_T(t_k,\omega_j)+\sum_{k=0}^{K}\gamma(t_k)q(t_k,\omega_j)\right\}.$$

The first term of the expression gives the average weighted loss at the multiplexor, the second gives that for token buckets, and the last one is the penalty assigned to the average waiting time in the multiplexor.

To illustrate the dependence of estimation error on the observation window size W_s and the prediction time T_d, we use the statistical modeling technique to compute the expected value of the (estimation) error given by where w_j denotes the j-th sample path and N_s denotes the number of sample paths used. The inverse of the signal-to-noise ratio (E_{SNR}) is used as another measure to evaluate the quality of prediction results:

$$E_{SNR} = (SNR)^{-1} = \frac{\sum e^2}{\sum (V(t_k))^2} = \frac{\left((1/N_s)\sum_{j=1}^{N_s}\left(\hat{V}(t_k, w_j) - V(t_k, w_j)\right)\right)^2}{\sum (V(t_k))^2}.$$

For any fixed window size, E_{SNR} increases with the increase of prediction time and appears to reach a plateau. As expected, E_{SNR} is smaller for larger Hurst parameters due to increasing of long-range dependence of parameters of random process. This is further illustrated in Fig. 2.

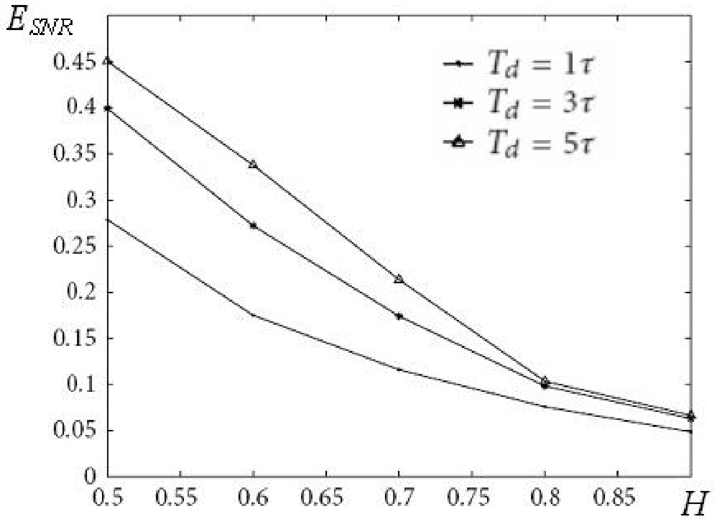

Fig. 2. Prediction errors versus Hurst parameter under constant delay time T_d

Research of characteristic properties of process is conducted forming of stream, which must be taken into account at the choice of parameters and structure of control system by the multi-speed shaper of traffic.

This discussion of the metering process has indicated that packets marked red are typically discarded. However, the immediate discarding of red-marked packets is a choice known as policing. An alternative method of dealing with non-conformant packets is known as shaping. Before explaining how shaping is carried out, it is necessary to review the mechanism where packets are queued at an egress port. Each egress port has a set of egress queues, which are allocated different priorities or weights.

The QoS mechanisms place packets into the appropriate egress queue, but the queues are of a limited length, so packets cannot be placed into them indefinitely. If the switch is congested, the queues may fill up and no more packets can be added, so even high priority packets can be dropped from the end of queues.

Developed to recommendation in relation to the choice of parameters of shapers and control system by them (necessary order of control system, structure of shapers, measuring devices of parameters of packages et cetera) depending on intensity of flows of data, their statistical descriptions and network structure.

Development of the Method of Adaptive Traffic Shaping.

1. The token generator TG_E throws down in the bucket of E tokens at a speed of E_{IR} in a second. If a bucket is filled, superfluous tokens are cast aside. Time of filling is $t_{fE} = E_{BS}/E_{IR}$.

2. The token generator TG_C throws down in the bucket of C tokens at a speed of C_{IR} in a second. If a bucket is filled, superfluous tokens are cast aside. Time of filling .

3. Tokens accumulate in the buckets of E and C. General length of temporal interval, occupied by a token in the bucket of E, is equal $\tau_e = \tau_{te} + \tau_{ge}$, where τ_{te} is duration of token in the bucket of E; τ_{ge} is duration of protect interval. General length of time interval, occupied by a token in the

bucket of *C*, is equal $\tau_c = \tau_{tc} + \tau_{gc}$, where τ_{tc} is duration of token in the bucket of *C*; τ_{gc} is duration of protect interval.

The number of tokens in the bucket of *E* is equal, in the bucket of C equal n_c. Then the general total size of tokens in the bucket of *E* is equal $T_e = n_e \cdot \tau_e$, in the bucket of *C* is equal $T_c = n_c \cdot \tau_c$. Duration of arriving package will designate through p_s.

4. Adaptation to the change of duration of input packages can be carried out as follows:
   - changing duration of token at permanent duration of protective interval;
   - changing duration of protective interval at permanent duration of token.

Both in that and in other case of speed of E_{IR} and C_{IR} will change to the limits, which depend on the maximal carrying capacity of, interconnect knot.

It's reasonable to adapt to the change to middle intensity of packets by the change of speeds of E_{IR} and C_{IR}.

The load metering and packets specification procedures are shown on Fig. 3.

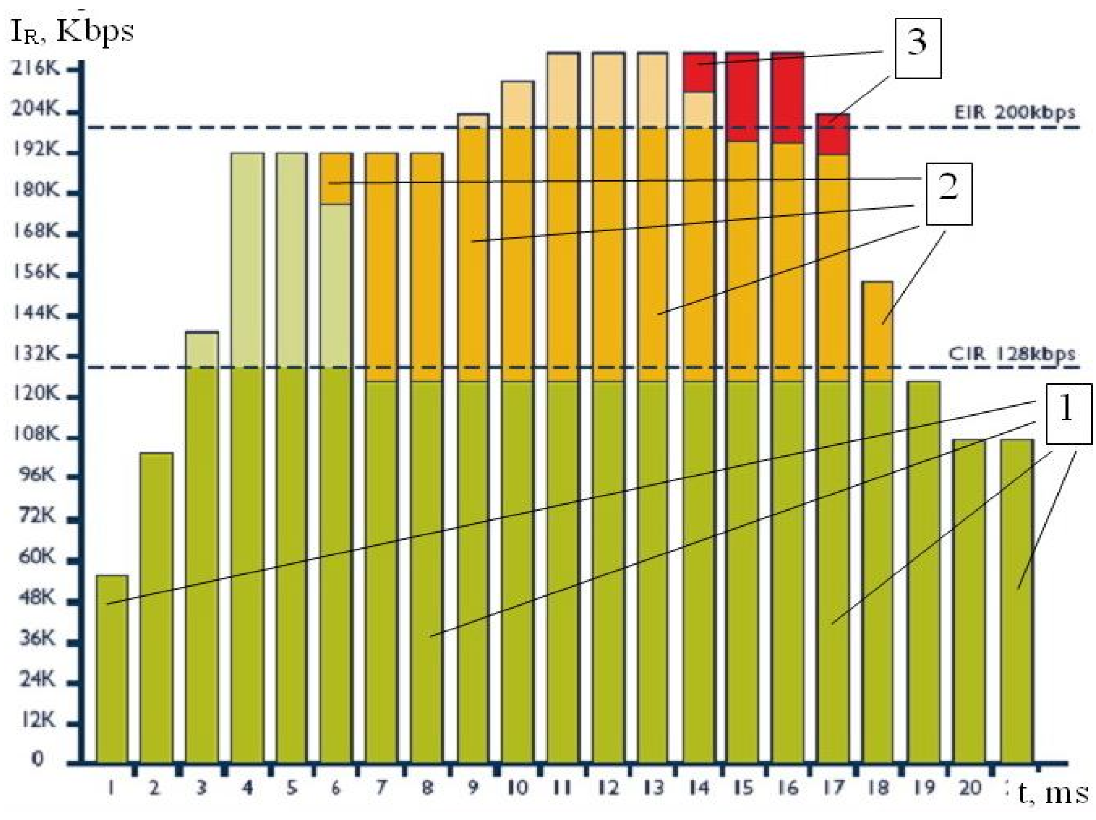

Fig. 3. Load metering and packets specification in traffic shaper. I_R – instant intensity of traffic flow. Packets 1 – high priority, packets 2 – middle, packets 3 – low (first turn dropping).

We consider traffic shaper with variable speeds C_{IR} and E_{IR}. They depend from speed and acceleration of intensity grows. The flow chart of multi-speed shaper is sown on Fig. 4. Adaptation to variable parameters of traffic and state of network nodes input to functional transformer (FT). Output signals are used for matching parameters of shaper.

Conclusion. It is possible to compensate the impact of communication delay causing performance degradation using the method of prediction of traffic variations and expected network overload. The method of LMSE presented in this paper improves the overall system performance and prevents network losses.

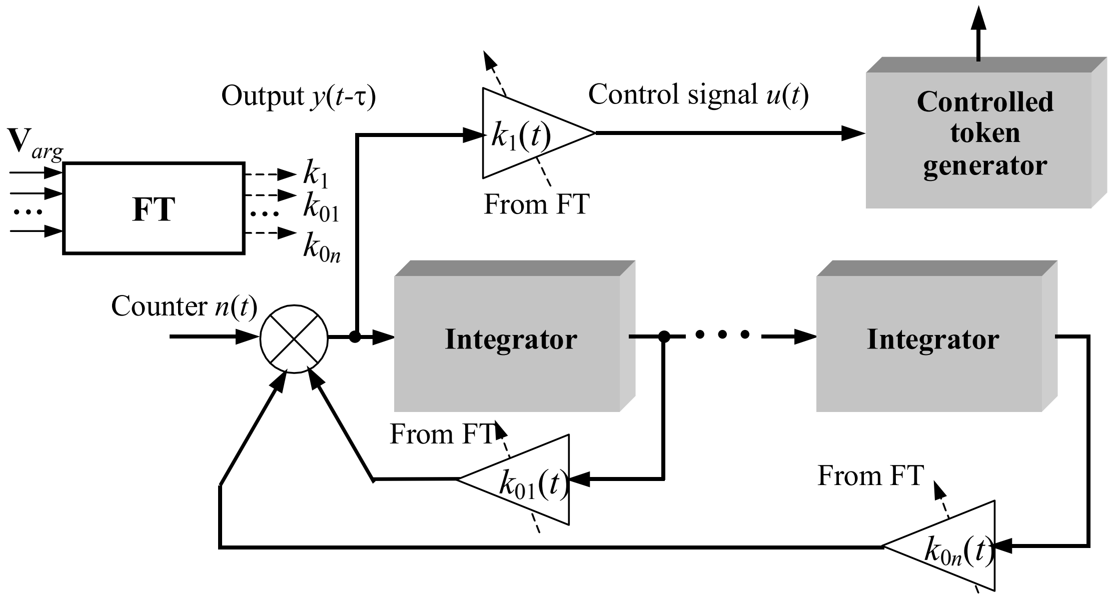

Fig. 4. Multi-speed traffic shaper.

The numerical simulation results presented have shown the effectiveness of the proposed predictive feedback control law. It was found that processes with larger Hurst parameter have better prediction performance. This result is expectable in considering long-range dependence of self-similar traffic characteristics. The results of this work also lead to a better understanding of the impact of Hurst parameters on network performance. In summary, this work provides a useful tool for design and optimization of future networks using predictive feedback control law thereby avoiding transfer instability. Moreover, the traffic shaping leads to decreasing of the range of self-similarity and more uniform distribution of moments of packets arriving.

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