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POLICING AND SHAPING OF DATA FLOWS AND CONTROL OVERLOAD IN SPECIALISED COMPUTER NETWORKS

Chang Shu. Policing and shaping of data flows and control overload in specialised computer networks. The problems of quality of service in the aeronautical computer networks with mobile nodes 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 delays of control data and compensating of delays due to prediction of traffic parameters in advance we decrease negative impact of these delays. The results of calculations of improvement of network performance are represented. 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. Proposed procedure of traffic shaping is rather simple and efficient. The results of calculations of improvement of network performance are represented.

***Keywords*:**computer network, overload, mobile node, quality of service, real-time system, network performance, compensating of delays, Hurst parameter, prediction of traffic parameters

Чанг Шу. Регулювання і формування трафіку і керування перевантаженнями в спеціалізованих комп'ютерних мережах. Досліджено проблеми якості обслуговування в авіаційних комп'ютерних мережах з мобільними вузлами. Розроблено метод управління мережами на основі розділення оцінки і управління в якості єдиної основи для систем адаптивного реального часу. З огляду на затримки даних контролю та компенсації затримок через передбачення параметрів трафіку ми заздалегідь зменшуємо негативний вплив цих затримок. Представлені результати розрахунків підвищення продуктивності мережі.

***Ключові слова*:** комп'ютерна мережа, перевантаження, мобільний вузол, якість обслуговування, система реального часу, продуктивність мережі, компенсація затримок, параметр Херста, передбачення параметрів трафіку

Чанг Шу. Регулирование и формирование трафика и управление перегрузками в специализированных компьютерных сетях. Исследованы проблемы качества обслуживания в авиационных компьютерных сетях с мобильными узлами. Разработан метод разделенного управления сетями на основе оценки и управления в качестве единой основы для адаптивных систем реального времени. С учетом задержек данных управления и компенсации задержек путем предсказания параметров трафика мы уменьшаем негативное влияние этих задержек. Представлены результаты расчетов повышения производительности сети.

***Ключевые слова*:** компьютерная сеть, перегрузка, мобильный узел, качество обслуживания, система реального времени, производительность сети, компенсация задержек, параметр Херста, предсказание параметров трафика

I. Introduction

Aeronautical computer network with mobile nodes has such specific features. First of all, it is the system of critical application, which is characterised by great spread in values of necessary calculating resources for optimum and extreme cases. All computer services must be represented in real time-scale under any conditions of implementation. Besides, it is complex system having huge number of networking and terminal equipment with large range of 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. At last, 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.

II. Problem statement

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 [5] 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 [1], 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.

Traffic prediction methods have been widely used in network management. By use of prediction techniques, that is, forecasting the future behaviour of the traffic, one can effectively prevent traffic jams, traffic congestion, and network crashes. Inspired by these ideas, we have applied prediction techniques [2,3] to solve the problems encountered in [1].

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. 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 optimise 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.

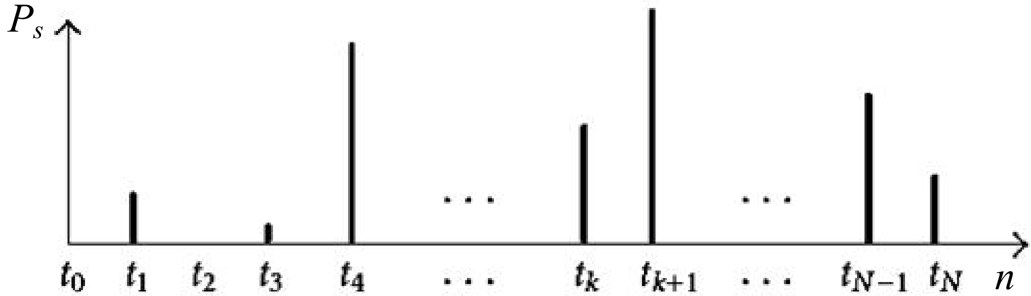

Fig. 1. General model of network traffic. P_s – packet size (bytes).

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 behaviour 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. 1, which is similar to those in [6].

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.

Unlike traditional algorithms of traffic shaping we propose Adaptation to the change of length and instantaneous intensity of entering packets can be carried out as follows:

- by changing length of token at permanent length of guard interval;
- by changing length of protective interval at permanent length of token;
- by changing size of "yellow range" [5];
- by changing size of data and token buffer memory.

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 $L(t_k)$.

For traffic shaping, a token bucket permits burstiness but bounds it. It guarantees that the burstiness is bounded so that the flow will never send faster than the token bucket's capacity, divided by the time interval, plus the established rate at which tokens are placed in the token bucket. See the following formula: $S_{fl\max} = C_{tb}/T_c + E_r$, where C_{tb} is token bucket capacity in bits, and E_r is established rate in bps, and $S_{fl\max}$ is maximum flow speed in bps.

In general, the traffic loss at the token buckets during the k_{th} time interval is given by $L_T(t_k) = \sum_{i=1}^{N} r_i(t_k) = \sum_{i=1}^{N} [V_i(t_k) - g_i(t_k)]$, 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

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

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.

To illustrate the dependence of estimation error on the observation window size W_s and the prediction time T_d, we use the statistical modelling 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.

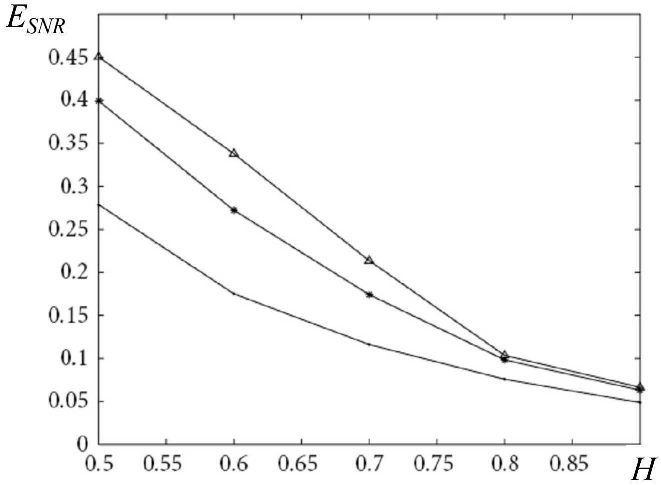

Fig. 2. Prediction errors versus Hurst parameter under constant delay time T_d:

$T_d = 1\tau$

$T_d = 3\tau$

$T_d = 5\tau$

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 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. Proposed procedure of traffic shaping is rather simple and efficient. The results of modelling shows that it is possible to limit the frequency of token generator till such value, when all input traffic would been received and then transferred without losses and retransmissions. 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 optimisation of future networks using predictive feedback control law thereby avoiding transfer instability.

References

1. Chang Shu. Statistics and prognosis the parameters of heterogeneous traffic in computer networks of critical application / Chang Shu // Наукові записки Українського науково-дослідного інституту зв'язку. – 2012. –№2(22). – PP. 56-60

2. Марпл мл. С.Л. Цифровой спектральный анализ и его приложения / С.Л. Марпл мл.– Москва : Мир, 1990. – 584 с.

3. Макхол Дж. Линейное предсказание. Обзор / Дж. Макхол // Труды института инженеров по электротехнике и радиоэлектронике. – 1975. – Т. 63, № 4. – С. 20-44.

4. Рабинер Л.Р. Цифровая обработка речевых сигналов / Л.Р. Рабинер, Р.В. Шафер. – Москва : Радио и связь, 1981. – 496 с.

5. Chang Shu. Shaping of traffic parameters and elimination of overload in aeronautical telecommunication networks // Наукові записки Українського науково-дослідного інституту зв'язку. – 2011. –№2(18). – PP. 52-57.

6. Виноградов Н.А. Анализ потенциальных характеристик устройств коммутации и правления сетями новых поколений / Н.А. Виноградов // Зв'язок. – 2004. – №4. – С. 10-17.

7. Гнеденко Б.В. Введение в теорию массового обслуживания / Б.В. Гнеденко, И.Н. Коваленко. – Москва: Наука, 1987. – 336 с.

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