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Comparative Studies of Methods for Accurate Hurst Parameter Estimation

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Introduction

The real-time applications such as VoIP, audio and video streaming, are both sensitive to delay and loss. As a result, statistical service guarantees have attracted a lot of research interest in the past decade. In this paper we focus on the studies of statistical service guarantees to individual flows.

Admission control has been proposed as the means to provide statistical service guarantee. As long as the system has resource capacity to provide the required service guarantee, the demanding data flow gets admitted.

The parametric-based admission control (PBAC) [7] allows providing hard service guarantees. The parametric-based admission control provides conservative decision and therefore provides the low network utilization.

In parametric-based admission control a PBAC algorithm uses the a priori source characterizations for incoming flows and for existing flows that have been in the system it uses simple summarizing of pre-specified characterizations, e.g. bandwidth.

With Constant Bit Rate (CBR) applications simple addition of pre-specified bandwidths is a sufficient solution for service guarantee - by means of resource optimisation. However, the pre-specified bandwidth technique is an inefficient approach to bandwidth allocation for Variable Bit Rate (VBR) applications. They are generally unaware in advance in terms of their specific bandwidth requirements.

To overcome such a challenge the measurement-based admission control (MBAC) has been studied and proposed in the literature [4, 5, 13]. In measurement-based admission control an MBAC algorithm uses the a priori source characterizations only for incoming flows.For the flows that already exist in the system it uses measurements to characterize them, so that higher network utilization can be achieved, particularly in comparison to parametric-based.

While admission control algorithms use different analytical bases for admission test, the different measurement characterizations are used. A number of empirical and analytical studies of traffic measurements from a variety of working packet networks have convincingly demonstrated that actual network traffic is self-similar or long-range dependent in nature. Studies identified evidences of self-similar behaviour in computer network traffic, as well as its severe implications in network performance [3]. The commonly considered measure of self-similarity is so-called Hurst parameter (H). That parameter has been chosen mainly due to the presence of burst traffic in several time-scales that leads to a higher end-to-end delay and packet losses.

For the resource allocation we proposed an algorithm [9] based on packet loss probability. For the evaluation of the packet loss probability the measured H parameter, packet arrival rate and available buffer memory are used.

The estimation of the Hurst parameter reveals a complicated problem. In real conditions the data set which is operated with is finite and therefore it is impossible to check whether a traffic trace is self-similar or not. This shows that it is necessary to examine various properties of self-similarity in traffic.

The first problem usually arises because it is impossible to make the conclusion that the analysed data have a self-similar structure because there are other influences that can lead to the same properties, e.g. a non-stationary presence.

The second problem concerns the fact that the estimation of Hurst parameter depends on many factors, e.g. the estimation procedure, the sample size, the sampling period, etc. This causes essential troubles when finding the most appropriate ‘H estimation’ for the current problem.

At present several methods of self-similarity from the time series estimation are known [10, 12]. The most popular approaches are the following: analysis of R/S (rescaled adjusted range) statistics, analysis of the variance–time plot, analysis based on specific properties of $S(\omega)$, Whittle estimation and analysis based on wavelet functions.

The present paper provides a thorough overview of currently known methods for Hurst parameter estimation and presents research results of accuracy levels of each of them. Moreover, paper shows the results gained using the Hurst parameter for determination of buffer sizes dependence on the estimation procedure and measurements sampling.

Hurst parameter dependence on the sampling period

As discussed above, the estimation of the Hurst parameter constitutes a complicated problem. Further in this section the problem of the Hurst parameter estimation of measurements with different sampling period is considered.

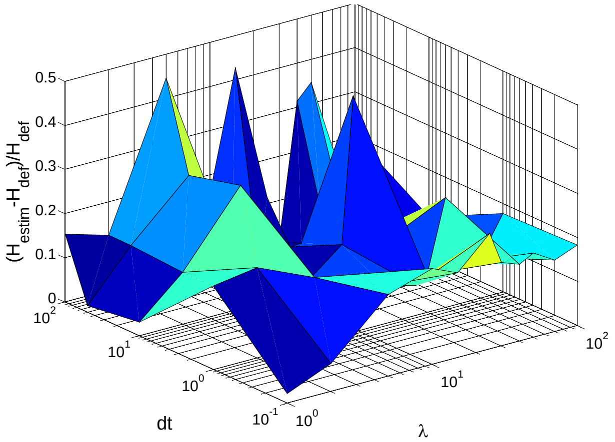

Fig. 1. Hurst parameter estimation accuracy with the Wavelet method and $H_{def} = 0.55$

Comparative results are presented for the following estimation procedure: R/S [6], aggregated variance [12] and wavelet [2, 10]. In our experiments the simplest function used for wavelet method resulted in quite accurate H parameter estimations and they were close to results of R/S and aggregated variance methods. However, such an accuracy level is not sufficient for practical purposes, e.g. packet loss probability, so a more complicated function is recommended for use.

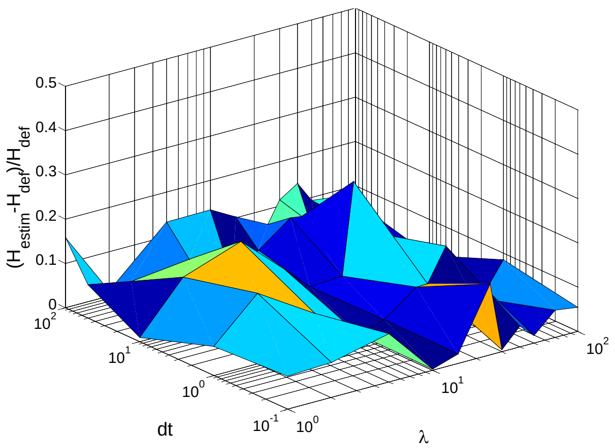

Fig. 2. Hurst parameter estimation accuracy with the R/S method and $H_{def} = 0.55$

For the mentioned Hurst parameter estimation procedures the input data series is used. The data series produces results according to measurements that consist of the packets arrival time. To produce the data series the numbers of arrived packets within each sampling period (Δt) are calculated. The data series correspond to packets per time unit, where time unit is equal to sampling period.

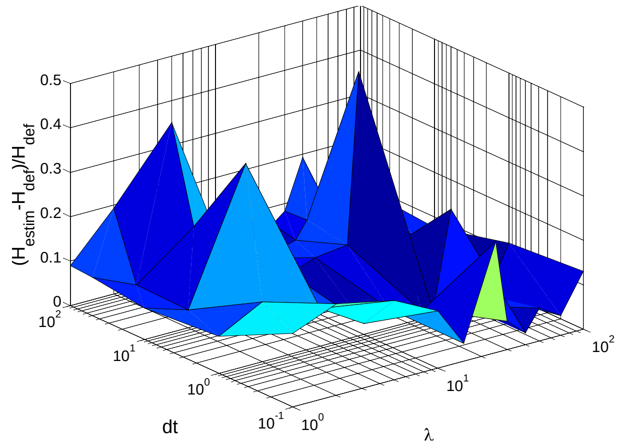

Fig. 3. Hurst parameter estimation accuracy with the aggregated variance method and $H_{def} = 0.55$

Fig. 1 – Fig. 6 present the relationships between estimated and defined H parameter dependence on the sampling period and packet interarrival rate for the different estimator functions and defined H parameter. Fig. 1 illustrates the relation for the Hurst parameter estimation accuracy for the wavelet method for the predefined H parameter that equals to 0.55. Fig. 2 and Fig. 3 respectively illustrate the relations for the Hurst parameter estimation accuracy for the R/S and aggregated variance methods for the predefined H equal to 0.55. Fig. 4- Fig. 6 illustrates comparable charts for the predefined H = 0.8.

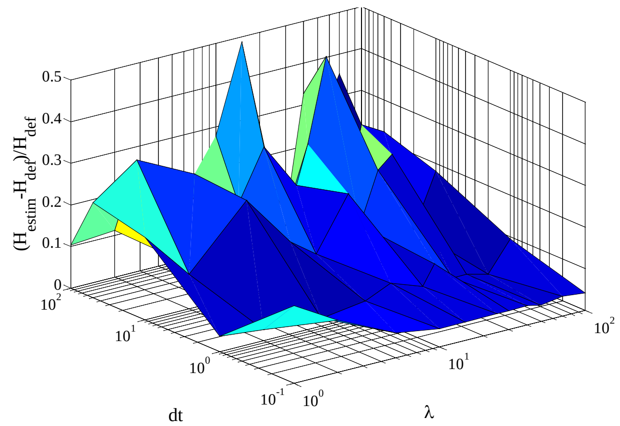

Fig. 4. Hurst parameter estimation accuracy with the Wavelet method and $H_{def} = 0.8$

On the basis of Fig.1 – Fig.3 it can be argued that the accuracy of Hurst parameter estimation has clear correlation to relationships between sampling period and the interarrival rate. The estimated H parameter for the traffic with low interarrival rate the accuracy does not depend on the sampling period (dt).

In contrary, the accuracy of the H parameter estimation for the traffic with high interarrival rate has critical dependence on the sampling period. The increasing of the sampling period causes the significant increase of the parameter estimation accuracy.

Another interesting conclusion can be made based on the charts. While the H parameter grows, the estimation accuracy becomes more stable depending on the sampling period. However, the accuracy does grow, which is especially valuable for the high interarrival rate.

Our experiments show that the closest Hurst parameter estimation can be obtained on the basis of the data series that were acquired from the measurements with the sampling period equalling to $\Delta t = 1/\lambda$, where λ - packet interarrival rate.

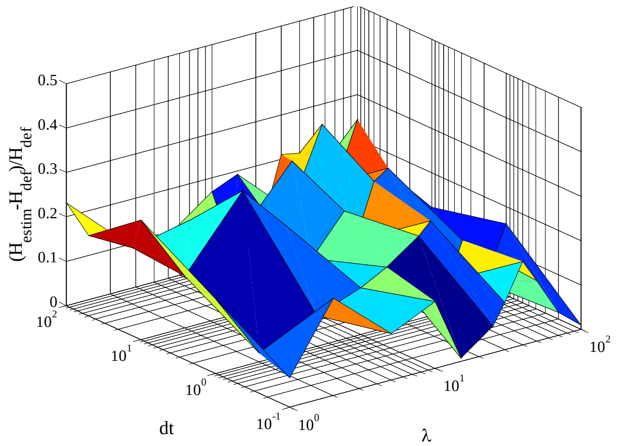

Fig. 5. Hurst parameter estimation accuracy with the R/S method and $H_{def} = 0.8$

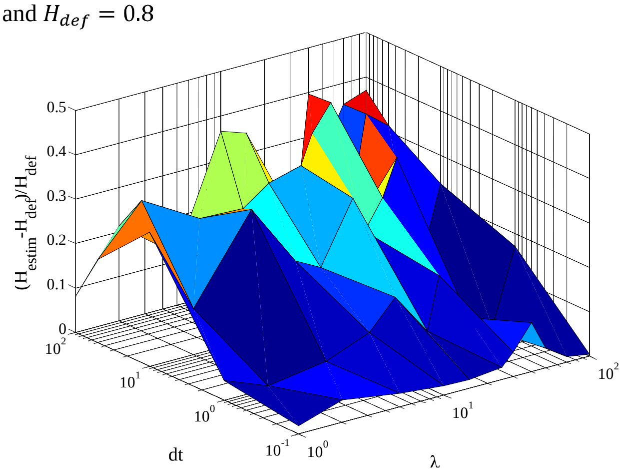

Fig. 6. Hurst parameter estimation accuracy with the aggregated variance method and $H_{def} = 0.8$

The accuracy of the Hurst parameter dependence on the sampling period raises a number of issues of the Hurst parameter practical usage.

The admission control described in [9] uses the Hurst parameter as the characteristic of the existing data flows used for decision making according to acceptance or reject of a newly arrived data flow. In case the estimated Hurst parameter is higher than the originated, the admission control algorithm will think that the system has higher resource utilization than it is. It will cause a high number of rejected requests and, therefore, the low network utilization (effectiveness).

Otherwise, if the estimated Hurst parameter is smaller than the originated, the admission control algorithm will think that the system has smaller resource utilization than it really is. Consequently, A higher number of requests will be admitted and cause the overutilization, i.e., high packet loss.

Buffer size dependence on the sampling period

This section presents a quantitative comparison of the Hurst parameter estimation using different methods. For these purposes the buffer size is chosen as the measure for comparison.

The different methods were used for the Hurst parameter with different estimation functions. The Hurst parameter was estimated for the traces with the different packet arrival rate and definite Hurst parameter. The arrival rate was chosen to produce the necessary network utilization ρ, that can be evaluated as follows: $\rho = \lambda/\mu$, where λ – packet arrival rate, and μ - packet service rate.

It can be seen that the inaccurate H parameter estimation has crucial effects on the system resource allocation - the buffer size. For the input traffic with the high interarrival packet rate and high H parameter even the small inaccuracy of the H parameter estimation cause enormous K value evaluation.

Another interesting note is that the relation $\frac{K_{origin}}{K_{estim}}$, where H parameters is estimated using the wavelet method, do not depend on interarrival rate under condition when the sampling period lies between 0.1 and 1 sec. If the sampling period is chosen higher than 1 sec, the buffer size will be estimated with high inaccuracy.

Discussion and conclusions

In the paper the comparative study of the Hurst parameter estimation is shown. Three well known methods were discussed. They are R/S, Whittle and Wavelet-based methods. Experiments show that the simplest wavelet method has the similar accuracy result as R/S and aggregated variance methods. Thus, it is possible to estimate H parameter more accurately using more precise wavelet methods, while the R/S and aggregated variance methods provide their best results.

The first important result is the sampling period dependency of all three estimation functions. The estimated Hurst parameters were calculated basing on the packet per time unit data series. The estimation accuracy varied for the data series produced of the same measurements but with a different sampling period. Our experiments show that the closest Hurst parameter estimation can be obtained on the basis of the data series that was acquired from the measurements with the sampling period equalling to $\Delta t = 1/\lambda$, where λ - packet interarrival rate.

Second, it has been discovered that the Hurst parameter cannot be applied easily for practical purposes. The small inaccuracy in Hurst parameter estimation can cause low utilization, in other words, high packet losses. The paper shows that the buffer size estimated according to defined and estimated Hurst parameter could have great ratio. For that reason, the MBAC that makes decisions based on Hurst parameters should be equipped with a high accuracy Hurst parameter estimator.

The third result is that wavelet method for the small sampling period gives the smallest ratio of the buffer size estimated basing on the theoretical and calculated H parameter. Such a result leads an opportunity to use the Hurst parameter estimation function based on wavelet method, in applications like MBAC for traffic characteristics estimation.It can be concluded that the wavelet-based Hurst parameter estimation function looks the most promising in MBAC. The use of this base function is able to provide the highest accuracy for Hurst parameter estimation. Further studies that include detailed research of the wavelet base functions would be useful.

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Over the last decade the traffic of the packet-based networks shows self-similar or long-range dependent nature. Such behaviour raises issues of accuracy in resource allocation and related guarantee required of QoS parameters for data flow. One of the popular mechanisms for QoS parameters guaranty is Measurement-based Admission Control (MBAC). In it’s turn, the efficiency of the MBAC mechanism is tightly related to the accuracy of traffic parameters estimation. The appropriate buffer size estimation is one of primary tasks in MBAC for QoS parameters guarantee. Hurst parameter which describes the level of self-similarity is used for this purpose. The accuracy of it’s estimation is important as otherwise underutilization or over-saturation of the system may occur that would cause high packet losses. The present paper provides a thorough overview of currently known methods for Hurst parameter estimation and presents research results of accuracy levels of each of them. Ill. 6, bibl. 13 (in English; abstracts in English, Russian and Lithuanian).

М. Куликовс, С. Шарковский, Э. Петерсонс. Сравнительное изучение методов точной оценки параметра Херста // Электроника и электротехника. – Каунас: Технология, 2010. – № 7(103). – С. 113–116.

В последнее десятилетие трафик сетей, основанных на пакетах, показывает себя как самоподобный или зависимый от большого диапазона. Для такого типа трафика чрезвычайно важна точность в распределении ресурсов и связанная с ним обеспечение необходимых параметров гарантий качества обслуживания для поступающих потоков данных. Одним из распространенных механизмов для обеспечения гарантий параметров качества обслуживания является контроль доступа, основанный на измерениях (MBAC). В свою очередь, эффективность механизма MBAC тесно связана с точностью вычислений параметров трафика. Определение соответствующего размера буферной памяти является одной из основных задач MBAC для гарантии параметров. Для этих целей используется параметр Херста, описывающий уровень самоподобности. Важность точности расчета этого параметра показывает то, что в случае неточности может произойти недостаточное использование или перегрузка системы, что приведет в высоким потерям пакетов.Настоящая работа приводит подробный обзор современных методов вычисления параметра Херста и предоставляет результаты исследования уровней точности для каждого из них. Ил. 6, библ. 13 (на английском языке; рефераты на английском, русском и литовском яз.).

M. Kulikovs, S. Sharkovsky, E. Petersons. Tikslus Hursto sistemos tyrimo metodų palyginimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 7(103). – P. 113–116.

Aprašomi Hursto sistemos kokybės ir priežiūros galimybių metodai. Pabrėžiama, kad tokiose sistemose svarbiausi veiksniai yra parametrų garantija ir priežiūros kokybė. Šiam tikslui pasiekti būtina naudoti Hursto kriterijus, kurie leidžia apskaičiuoti sistemos perkrovas ir informacijos srautų nuostolius. Pateikiami tikslumo tyrimų rezultatai. Il. 6, bibl. 13 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).