Integral measurement process of incoming traffic for Measurement-Based Admission Control

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Abstract— **The real-time applications are both sensitive to delay and loss. As a result, quality of service guarantees have attracted a lot of research interest in the past decade. Dynamic management of system parameters like bandwidth and buffer capacity allows to gain essential performance benefits while quality of service guarantees are met. For the recent years a method of admission control based on measurements have received a wide recognition. MBAC needs to estimate input traffic parameters to make a decision about allowing the flow into the system with limited resources of buffer capacity and bandwidth of output channel. The present paper shows several solutions to minimize possible errors of flows parameters estimation which is critical for making the correct decision about a new flow allowance.**

I. INTRODUCTION

Dynamic management of system parameters like bandwidth and buffer capacity allows to gain essential performance benefits while quality of service guarantees are met. For the recent years a method of admission control based on measurements have received a wide recognition. MBAC needs to estimate input traffic parameters to make a decision about allowing the flow into the system with limited resources of buffer capacity and bandwidth of output channel. Intensity of incoming flow of packets and the self-similarity parameter (Hurst parameter – H) of incoming traffic need to be calculated to assign the volume of outgoing channel and buffer capacity.

The present paper shows several solutions to minimize possible errors of flows parameters estimation which is critical for making the correct decision about a new flow allowance.

Firstly, recommendations for determination of observation period T are presented. It cannot be chosen too long as the character of current traffic may change suddenly and the system of this traffic will not be able to spot that hop. And it cannot be chosen too low as it will not provide credible results.

Second, calculation methods of such a significant MBAC parameter as sampling period are presented. If the parameter is too high, uncertainty in flow parameters evaluation will increase, as well as it will be impossible to observe each incoming packet because of lack of time spent for processing [7],[3].

II. THE PROCESS OF INCOMING TRAFFIC PARAMETERS MEASUREMEN

The intensity of incoming packet flow and self-similarity parameter of incoming traffic need to be estimated so that calculation of outgoing channel load and buffer capacity is possible. These operations have to be done for further decision about allowance of the flow to the system with limited resources, e.g. bandwidth and buffer capacity.

The incoming flow is analyzed by accumulating data about it during the periods of time T. Using these periods the system shows the results of incoming flow analysis which are further used to take a decision about the new flow access to the system. If these time periods are T-fixed, the graph of incoming flow changes and measurements looks as follows (Fig. 1):

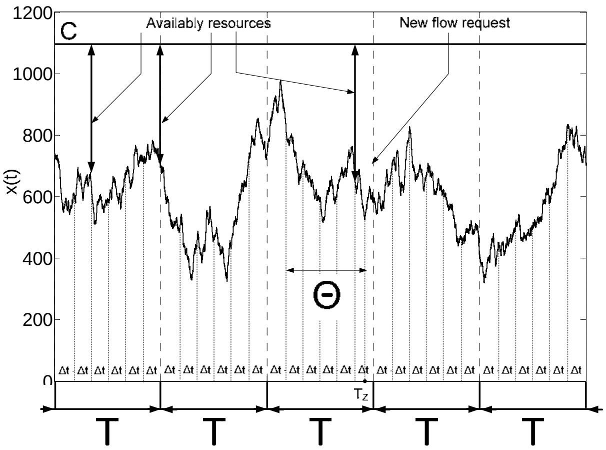

Fig.1 The graph of incoming flow changes and measurements with the fixed periods.

The measurements of the flow parameters are taken during the discrete time periods Δt. The flow data during the time period Δt can be denoted as $x(i)$, where i is Δt period. For example, $x(2)$ is data of the aggregated number of packets in the second period Δt_i.

Following, we are going to present the case, why it is important to define Δt. As an example we are going to present the Hurst parameter estimation.

In order to estimate a Hurst parameter of the incoming traffic, a wavelet transformation procedure can be chosen. The arguments in the favor of this type of transformation are the following. It is quick and sufficiently accurate method of Hurst parameter evaluation [5].

The importance of its accurate evaluation lies in the fact that for the traffic with a high Hurst rate buffer overload probability along to the growth of its size decreases not at the exponent, as it happens in mass service Markovian systems, but in the way of grade. An inaccurate estimation can cause either great system underutilization or dramatically overflows.

Fig. 2 presents the graph, reflecting the error of Hurst parameters evaluation using wavelet transformation. The very simple Haar wavelets have been used for estimations. As a traffic model a Fractal Renewal Process with Pareto

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distributed packets incoming time with Hurst parameter H=0.85 has been chosen. A process length is one day.

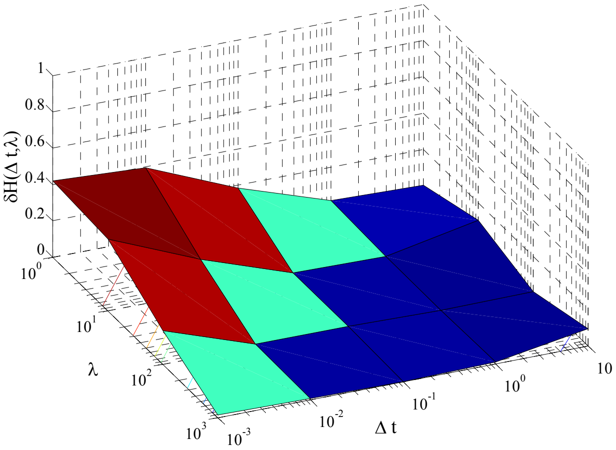

Fig.2 Estimation Error of Hurst Parameters with Haar Wavelet, H=0.85.

The given traffic intensity equals $\lambda = 1, 10, 100, 1000$ packets per second. Time interval is $\Delta t = 0.001, 0.01, 0.1, 1, 10$.

On the graph it is clearly seen, that Δt plays important role in accurate H parameter estimation. Following, several solutions to minimize possible errors of flows parameters estimation are presented.

III. The Recurrent Algorithm of Parameter Evaluation

For the outgoing channel the bandwidth capacity C is known. Thus, using the example given above, the remained resources are $C - \frac{X(2)}{\Delta t} = c_2$. The level the incoming flow influences the system corresponds to the utilization of channel ρ. In the case used before the utilization coefficient is the following:

$$\rho(2) = \frac{X(2)}{\Delta t} / c. \tag{1}$$

It has to be mentioned that besides the last time period the system accumulates data about any parameter during a longer time period too. Thus, there is a probability this fact can be used.

The target parameter is intensity of incoming flow λ_i at period i. The intensity assigns the number of packets $x(i) = \lambda_i \Delta t$ that enter the system on i period within Δt time period. The flow intensity as well as the other incoming flow parameters is declared by the source at the moment of request about available network channel resources.

The value declared in the request, the incoming flow intensity, for example, is not known for sure and get assigned roughly.

In general case, any declared parameter is designated as A. For it's uncertainty this parameter can be considered as probability density $P(A)$ with mathematical expectation A_0 and variance σ_A^2.

In fact communication system does not receive a true variable A_i but an accidental value $a_i = A_i + \xi_i$ influenced by inaccuracy and observation limits. Assume that these variables are independent and identically distributed. Also assume that "noise" of observation has probability density with the finite variance σ_a^2.

Taking into consideration these data the system determines a^* which is a evaluation. The discrepancy: $\varepsilon = (a - a^*)^2$.

During r periods the system gets a vector of parameters values $\mathbf{a}^{<r>} = (a_1, a_2, \dots, a_r)$. A specific risk R while choosing the optimal value of a^* parameter:

$$R = \int_{-\infty}^{+\infty} (a - a^*)^2 \cdot P(a/\mathbf{a}^{<r>})\, da, \tag{2}$$

where $P(a/\mathbf{a}^{<r>})$ is an a-posteriori condition of of variable a probability density with the preset vector $\mathbf{a}^{<r>}$. The optimal evaluation value a^*_{opt} is gained by minimization of the specific risk R that leads to the following:

$$a^*_{opt} = \int_{-\infty}^{+\infty} a \cdot P(a/\mathbf{a}^{<r>})\, da = M[a/\mathbf{a}^{<r>}]. \tag{3}$$

According to identification theory [9] the best distribution $P(a/\mathbf{a}^{<r>})$ with the limitations mentioned above should be normal.

Using the parameters of a normal distribution in Eq. (3) it looks as following:

$$a^*_{opt} = M[a/\mathbf{a}^{<r>}] = \frac{[A_0 \frac{\sigma_a^2}{\sigma_A^2 \cdot r} + \frac{1}{r}\sum_{i=1}^{r} a_i]}{(\frac{\sigma_a^2}{\sigma_A^2 \cdot r} + 1)}. \tag{4}$$

This evaluation expression results into a particular case when the measurements of parameter variables are produced without lapses, i.e. when $\sigma_a^2 = 0$.

In that case the optimal value of the parameter being evaluated will be:

$$a^*_{opt} = \frac{1}{r}\sum_{i=1}^{r} a_i. \tag{5}$$

This value is formed at r period of flow observation and can be denoted as $a^*_{opt}(r)$. The expression can look differently:

$$a^*_{opt}(r) = \frac{1}{r}\sum_{i=1}^{r} a_i = \frac{r-1}{r} \cdot \frac{1}{r-1}\sum_{i=1}^{r-1} a_i + \frac{1}{r} a_r, \tag{6}$$

i.e.

$$a^*_{opt}(r) = a^*_{opt}(r-1) + \frac{1}{r}\big(a(r) - a^*_{opt}(r-1)\big). \tag{7}$$

The later equation leads to the algorithm of parameter evaluation: on another r step of observation the optimal value of the parameter turn into mathematical expectation of the parameter gained at the previous $r-1$ stage of observation, plus the correction that is equal to one r of deviation: $\frac{1}{r}\big(a(r) - a^*_{opt}(r-1)\big)$.

The recurrent expression that has been calculated above (7) belongs to the class of stochastic approximation in its simplest form [8]. Thus, in the end of time period T the described approximation procedure results the formation of data about a parameter or parameters in the system.

Further, the evaluation procedures when a new flow is requested for the access to the operating flow will be described.

At the moment t_Z a request for the access of a new flow is received which needs resource more than the remained for the moment Δt_{Z-1} (a moment of giving the result for the previous measurements time period). In this case the system will not allow a new flow in spite at the moment t_Z the system has enough resources. Such a situation leads to the errors in the work of MBAC.

IV. Suggestions for System Work Improvement Using Minimization of Errors.

Firstly, the observation period T has to be determined. It cannot be too long as the character of the current traffic may change suddenly and the system will not be able to note that change. Therefore, the appropriate value for the period T can be the correlation interval τ_k. The flow can change its statistical parameters after this interval. Thus:

$$T = \tau_k \tag{8}$$

The second parameter of MBAC has to be the period Δt. If it is high, a high uncertainty in the evaluation of the flow parameters appears. The most accurate option is the observation of each incoming packet. But it is impossible due to time losses of processing.

The definition of the time period has to take into account the flow character as this is observed in the self-similar traffic [2]. Using recommendations of the present work the following suggestions are proposed.

There is no necessity to expect the end of the period T at the incoming of a new flow at the moment t_Z. The evaluation of the working flow can be done using the accumulated data from periods $\theta \ll T$ on the basis of the following expression:

$$I(x,y) = \\ = \frac{1}{2}\left\{1 + (t-\theta)^{2H} \times \right. \\ \left. \times \left[1 - \frac{[t^{2H} + (t-\theta)^{2H} - \theta^{2H}]^2}{4t^{2H}(1-\theta)^{2H}}\right] \frac{(\theta - \Delta t)}{b}\right\} \tag{9}$$

where $I(x,y)$ is the information volume that is gained by the destination y from the source x during the changes for time θ previous to the moment of taking the decision t, for example $t = t_z$; H – Hurst parameter; Δt – period between the countdowns in the traffic $X(t)$, and $b = (\theta - \Delta t)\sigma_z^2$, where σ_z^2 is the variance of packets number at single measurement.

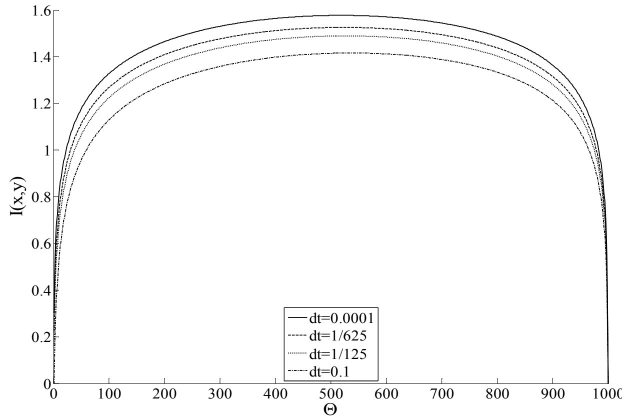

Fig. 3 $I(x,y)$ depending on θ with various Δt for the H=0.5.

Building the relationship $I(x,y)$ from θ (time needed to check and process the measurements), it can be seen that $I(x,y) \to max$, if θ is $\frac{1}{2}$ of the moment of the last evaluation t_i and the moment of taking the decision t. In the example used in the paper, $t = t_z$ and is equal to the moment of getting the request for the new flow.

The constructed graph (Fig.3 – Fig.5) shows that the necessary period of measurements and processing decreases while the self-similarity coefficient increases (H). It is logical, as with the increase of H, flow correlation grows too. Therefore the flow can be observed using the shorter period of time.

At this point a conclusion about the time period Δt between the countdowns of incoming flow $X(t)$ can be made. It is possible to create a family of curves $I(x,y)$ depending on θ with various Δt. Based on this argument it is possible to determine the period between the countdowns Δt^* while $I(x,y)$ are at their max.

The Fig. (3) – Fig. (5) shows the $I(x,y)$ depending on θ with various Δt. For the charts Δt was chosen as follows: $10^{-4}, \frac{1}{625}, \frac{1}{125}, 10^{-1}$ that are depicted with solid, dashed, dotted and dotted-dashed curves respectively. The Fig. (3) – Fig. (5), presents depending for the H parameters $H = 0.5, 0.75, 0.95$ respectively.

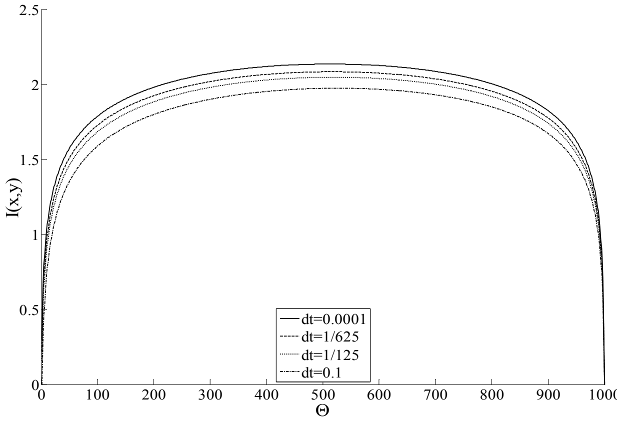

Fig. 4 $I(x,y)$ depending on θ with various Δt for the H=0.75

The graphs show that Δt and θ depend on the self-similarity power (H). The procedure described belongs to the case that evaluates the flows already existing in the system when the evaluation of aggregated current flow in the system takes place using the periods T with the gradual recurrent precision of the flow parameters with sub-periods $\Delta t \ll T$.

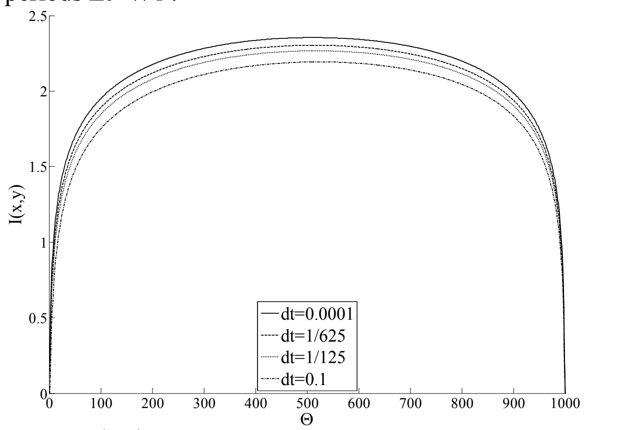

Fig. 5 $I(x,y)$ depending on θ with various Δt for the H=0.95

Next, the case of initial MBAC starting. The system starts to receive the requests for access of the first flow. Data about it declared by client can inform the system about an expected intensity of the flow (with some errors). The other flow parameters, a self-similarity level, for example, might be unknown. In this case the initial period of the accumulated data about unknown flow and observation frequency are chosen.

V. Selection of initial length S and Sampling period δ.

For the initial selection of observation length (S) and sampling period (δ) we propose to use the probe. Clearly, the more measurements, the more accurate are the results. For this reason the period between the countdowns δ is thought to be reduced. However, there is no point in making δ too short. Therefore, the worst case is chosen, which the Poison character of the flow is, i.e. it is not correlated. If the declared intensities of the flow λ are known, the period δ between the countdowns can be taken as equal to correlation period of Poison flow. This period can be determined and equals to $\delta = \frac{1}{\lambda}$, and it's correlation function is $K_x(\tau) = e^{-2\lambda|\tau|}$. The larger the observation period S is, the more accurate are the measurements. According to [1] the measurements error $\beta = \frac{D}{m-1}$, where D is the process variance and m is the number of measurements ($m = \frac{S}{\delta} = S\lambda$). Poison process variance represents $D = K_x(0) = 1$. Measurements error can be expressed in the following way:

$$\beta = \frac{D}{m-1} = \frac{1}{S\lambda - 1} \approx \frac{1}{S\lambda}, \text{ where } S\lambda \gg 1 \quad (10)$$

If the measurments error is preset $\beta^* = 1\%$, than $S = \frac{1}{0.01 \cdot \lambda} = \frac{100}{\lambda}$.

The resulting graph of the observation and measurements process looks as it is shown on Fig.6.

At the initial stage of research that studies the flow with the length S, the observation are taken in the period $\delta \ll \Delta t$, i.e. in the periods between the incoming packets. Further, on the basis of gained statistics, the correlation coefficient τ_k which equals T gets calculated. After the period T_1 ends, the flow analysis for time S is commenced again and a new correlation period is calculated, as well as a new period T_2 is assigned.

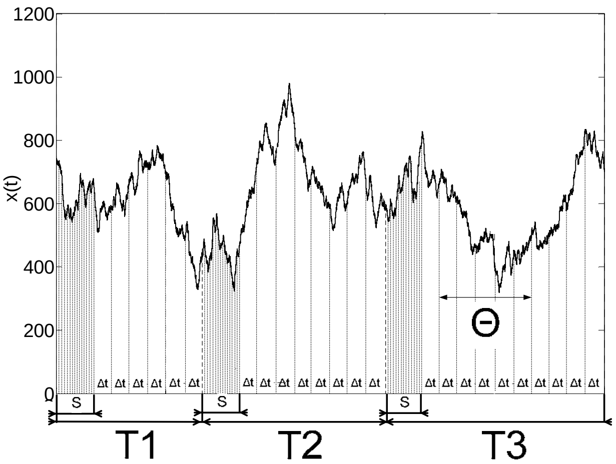

Fig. 6. An integral measurement process of incoming traffic for MBAC

If before the end of period T_2 a new flow at the moment t_z tries to enter the system, than on the basis of data gained for the past period t_z that can be estimated using the formula (10) the parameters of the current flow and resources remained for the new flow connection to the system are clarified.

The parameters of the flow that is being connected have to be declared. At least, their packet income intensity has to be preassigned. Further, the availability of throughput and buffer capacity resources have to be discovered. This would provide the parameter specified by QoS agreement, for examples the probability of packets loss P^*_{Loss}. The value of the Hurst coefficient (H) is set by the results of existing flow measurements.

For P_{Loss} calculation on the basis of the declared parameters the tabulated correlations gained on the basis of article [6] can be applied.

If $P_{Loss} < {P_{Loss}}^*$, than the new flow is given an access into the system. Otherwise, it does not happen.

Taking into consideration a well known fact that the self-similar process has a group character, it is possible to produce dynamic management of the system parameters like throughput and buffer capacity on the basis of suggestions proposed in the articles by [1] and [2].

VI. CONCLUSIONS.

Several solutions for the possible errors of flows parameters estimation minimization have been discussed.

In the paper the recurrent algorithm of parameter evaluation on n step of observation was presented. The recurrent expression belongs to the class of stochastic approximation. Thus, in the end of time period T the described approximation procedure results in nthe formation of data about a parameter or parameters in the system.

Solutions for observation and sampling period are proposed for both initial values selection and on-going estimation.

For the case when the flows are already admitted and the character of the current traffic may change suddenly the correlation interval τ_k has been proposed for use.

The maximization of $I(x,y)$ depending on θ with various Δt grant the sampling period Δt estimation. It was shown that the necessary period of measurements and processing decreases while the self-similarity coefficient increases (H).

For the initial values of the system the important results have been gained. If the declared intensities of the flow λ are known, the period δ between the countdowns can be taken as equal to correlation period of Poison flow. This period can be determined and equals to $\delta = \frac{1}{\lambda}$. The initial data flow observation period should be $S = \frac{1}{\beta \cdot \lambda}$, where β is a measurements error.

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